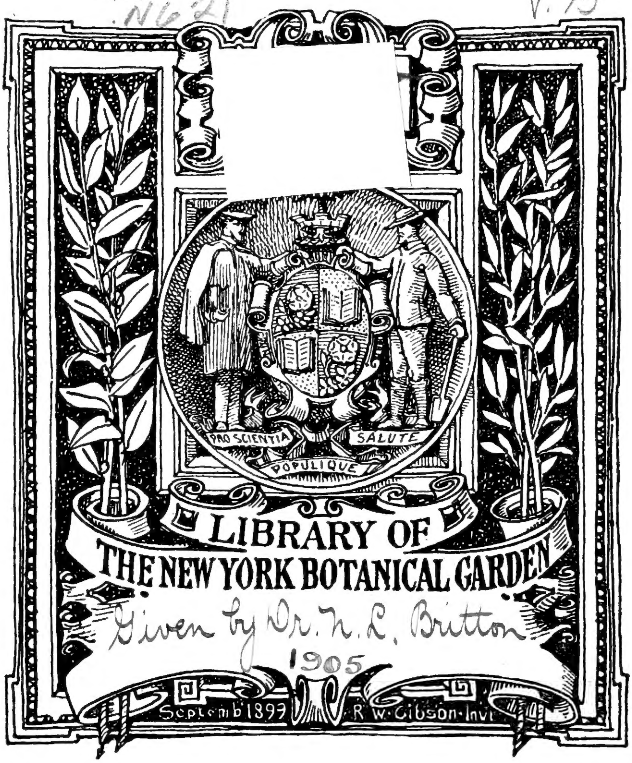
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# ANNALS

OF THE

# NEW YORK

# ACADEMY OF SCIENCES

VOLUME XV

1904

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Editor:

CHARLES LANE POOR

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New York
Published by the Academy

The New Era Printing Company
Lancaster, Pa.

## NEW YORK ACADEMY OF SCIENCES

OFFICERS, 1905

*President*—JAMES F. KEMP, Columbia University.
*Recording Secretary*—HERMON C. BUMPUS, American Museum.
*Corresponding Secretary*—RICHARD E. DODGE, Teachers College.
*Treasurer*—CHARLES F. COX, Grand Central Depot.
*Librarian*—RALPH W. TOWER, American Museum.
*Editor*—CHARLES LANE POOR, 4 East 48th Street.

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*Chairman*—ERNEST R. VON NARDROFF, 360 Tompkins Ave., Brooklyn.
*Secretary*—C. C. TROWBRIDGE, Columbia University.

### SECTION OF BIOLOGY

*Chairman*—W. M. WHEELER, American Museum.
*Secretary*—M. A. BIGELOW, Teachers College.

### SECTION OF GEOLOGY AND MINERALOGY

*Chairman*—EDMUND O. HOVEY, American Museum.
*Secretary*—A. W. GRABAU, Columbia University.

### SECTION OF ANTHROPOLOGY AND PSYCHOLOGY

*Chairman*—F. J. E. WOODBRIDGE, Columbia University.
*Secretary*—R. S. WOODWORTH, Columbia University.

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## SESSION OF 1905

The Academy will meet on Monday evenings at 8.15 o'clock, from October to May, in the American Museum of Natural History, **77th Street and Central Park, West.**

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# TABLE OF CONTENTS OF Vol. XV.

VOL. XV PART I

# ANNALS

OF THE

# NEW YORK ACADEMY OF SCIENCES

Edior:

CHARLES LANE POOR

The New Era Printing Company

Lancaster, Pa.

[ANNALS N. Y. ACAD. SCI., XV, No. 1, pp. 1–108, August 31, 1903.]

# RECORD OF MEETINGS

OF THE

# NEW YORK ACADEMY OF SCIENCES.

**January, 1902, to December, 1902.**

HENRY E. CRAMPTON, *Recording Secretary.*

## BUSINESS MEETING.

JANUARY 6, 1902.

Academy met at 8:15 P. M., Professor William Hallock presiding. The minutes of the last business meeting were read and approved.

There being no business to come before the Academy, the Academy adjourned at once.

RICHARD E. DODGE,
*Recording Secretary.*

## SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

### January 6, 1902.

Section met at 8:20 P. M., Professor Hallock presiding. The minutes of the last meeting of Section were read and approved.

The following program was then offered:

**William Hallock,** The Magnetic Disturbance of Steel Wire Plumb-bobs.

**William Hallock,** A Thermograph for Soil Temperature.

**H. C. Parker,** The Variation of Contact Resistance with Change of Electromotive Force.

### Summary of Papers.

Professor **Hallock** stated that in the course of the work in the very deep shaft of the Tamarack Mining Co. on Lake Superior it had been found desirable to plumb down certain points from the surface. The plumb-lines used were of No. 24 piano wire and the weights were fifty pounds of iron. At first the lines were 16.33 feet apart at the top and they were later moved to 17.66 feet The remarkable observation was made that in the first case they were 0.08 feet and in the second case 0.07 feet farther apart at the base than at the top. It was pointed out that a deflection of such an amount could not be explained as due to the gravitational attraction of the walls of the shaft for the nearer plumb-bob. Professor Hallock suggested that the effect was probably due to the magnetization of the wire and the consequent repulsion of the north poles at the bottom. In order to test the possible applicability of this theory a number of experiments were made in the research shaft at Columbia University which gave much corroborative evidence. Two plumb lines, about 85 feet long, were suspended in the shaft. One was of copper wire and the other of iron wire about 0.03 inch in diameter. Lead weights were attached and it was found that the lines were about $\frac{1}{75}$ in. closer together, at the bottom, when the iron line was south of the copper than when it was north. Two lines of iron wire were also used and the distance apart at top

and bottom measured. The deflections obtained were of the same order of magnitude as those produced by the earth's field. The deflections thus obtained give evidence of magnetic forces of sufficient magnitude to explain the deviations observed in the plumb-lines in the Tamarack shaft.

Professor **Hallock** also described a form of recording thermometer which he had lately devised. It consists of a large copper bulb connected by means of capillary copper tubing to a series of cells similar to those used in the construction of aneroid barometers. The bulb, tube and cells were filled with oil and the recording mechanism attached to the aneroid cells.

Mr. **H. C. Parker** gave the results of some experiments he had made on the variation of contact resistance with change of electromotive force. The resistance used in the experiments consisted of oxide of manganese on cobalt glass, the new form of standard high resistance described in a previous paper given before the academy. The electromotive force employed consisted of 10, 50, and 100 dry cells, respectively. It was found in every case that the resistance decreased with increase of electromotive force. This decrease might be only a small per cent. or the resistance might be reduced to a small fraction of the original value. Improving the contacts rendered this change in resistance much less marked. It was suggested that this decrease in resistance when the electromotive force was increased might be due to a kind of coherer action taking place at the contacts. Very high resistances measured by the electrometer method were found practically to obey Ohm's law. It was pointed out that in such cases the contact resistance was probably only a small portion of the entire resistance.

Section adjourned.

F. L. Tufts,
*Secretary.*

## SECTION OF BIOLOGY.

January 13, 1902.

Section met at 8.15 P. M., Professor C. L. Bristol presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered:

**Franz Boas,** The Relation between the Variability of Cells and that of Organisms.

**Gary N. Calkins,** Degeneration in Paramœcium and so-called Rejuvenescence without Conjugation.

**Henry E. Crampton,** Natural Selection in Samia cecropia.

## Summary of Papers.

Professor **Boas,** in his paper, which has been printed in full in *Science* for January 3, 1902, established the following conclusions: "(1) The elements of organisms are more variable than the organisms themselves. (2) The elements of organisms vary in correlated groups. (3) The characteristics of the variability of an organism depend upon the correlations of its constituent elements, so that a knowledge of these correlations will enable us to determine the characteristics of the variability of the organism." (4) It was also pointed out that skew distribution of variations does not necessarily indicate selection, or instability of type, but may occur in stable forms.

Dr. **Calkins** presented the history of two individuals, *A* and *B*, of *Paramœcium caudatum*, from different localities, which were isolated February 1, 1901. These were fed on twenty-four hour hay-infusion and the number of divisions recorded at periods of from one to three days throughout the year, one individual being isolated each time. Conjugation occurred for the first time, among the extras, in May. This period was followed, in July, by well-marked degeneration of both *A* and *B*, which went so far that nearly all of the stock was lost. The survivors were stimulated to renewed activity by treatment with extract of lean beef. After three months of normal and active divisions, another period of conjugation occurred. This again was followed by degeneration and again the cultures were saved by treatment with beef-extract. At the present date (Jan. 13), *A* is in the 416th generation and *B* in the 375th generation, and no conjugation has taken place in the direct line of the cultures. Thus far the experiments have yielded the following results: (1) *Paramœcium* unquestionably passes through more

or less regular cycles of activity and weakness. (2) The period of weakness is preceded by one of greater dividing-activity. (3) The period of weakness ends in death, provided the diet (hay-infusion) remains the same. (4) Beef-extract, without conjugation, restores the weakened functions of growth and division. (5) Exogamous conjugation of *A* and *B*, if followed by the same diet (hay-infusion), does not restore these weakened activities, but is soon followed by death. (6) Exogamous conjugation between wild gametes, and followed by hay-infusion diet, results in normal growth, division, and life. (7) Endogamous conjugation does not differ from exogamous conjugation. The ex-conjugants live and divide normally if fed for a time with beef-extract, but die if fed directly with hay-infusion. (8) One intra-cellular effect of beef-extract upon weakened *Paramœcium* is the formation of "excretory granules." Another is the disintegration of the old macronucleus. (9) A few conclusions to be drawn are: (*a*) a change of diet is necessary for the continuance of vital activities; (*b*) the equivalent of parthenogenesis in higher animals may be induced by change in diet; (*c*) conjugation, by itself, does not "rejuvenate"; (*d*) conjugation probably has some other significance than that usually accepted, though what this significance may be is not indicated, thus far, by the experiments.

Professor **Crampton** presented the results of a statistical study upon pupæ of *Samia cecropia*. Twenty-five characters were determined for a lot of 456 pupæ, the measurements were tabulated, and the usual constants of the curves of variation were ascertained, viz., the range, mode, mean, standard deviation, and coefficient of variability. It was found that only 349 of these pupæ produced perfect moths at the time of metamorphosis, the others being imperfect to a greater or less degree, and therefore presumably eliminated as far as reproduction is concerned. When, now, the former class was compared, sex by sex, with the whole group of pupæ, it was found to be a selected class of the less variable individuals, while the more variable ones were eliminated. Selection is therefore "periodic" in the sense of Pearson. The fact of primary interest appears

when this case is contrasted with that of the introduced *P. cynthia.* As reported last spring, selection in the latter species is similarly of the less variable individuals, but is "secular" as well, that is, the perfectly metamorphosing pupæ form a class by themselves, with a type which differs from that of the whole group. It was pointed out that the real basis of selection was probably a correlative one, a physiological "fitness" depending upon the proper coördination or correlation of the various parts of the organism.

HENRY E. CRAMPTON,
*Secretary.*

## SECTION OF GEOLOGY AND MINERALOGY.

JANUARY 20, 1902.

Section met at 8:15 P. M., Dr. A. A. Julien presiding. The minutes of the last meeting of Section were read and approved.

The following program was then offered:

**R. P. Whitfield,** OBSERVATIONS ON AND EMENDED DESCRIPTION OF HETEROCERAS SIMPLICOSTATUM WHITF.

**R. P. Whitfield,** DESCRIPTION OF A NEW TEREDO-LIKE SHELL FROM THE LARAMIE GROUP.

**James Douglas,** NOTES ON THE RIO TINTO COPPER DISTRICT.

### SUMMARY OF PAPERS.

In the first paper Professor **Whitfield** emended and elaborated the description of the ammonite, *Heteroceras simplicostatum* which he gave originally in the Newton and Jenney Report on the Black Hills;[1] the new observations being based upon material collected in July, 1901, for the American Museum of Natural History by Dr. E. O. Hovey. The present material shows conclusively that the three genera, *Hamites*, *Ancyloceras* and *Heteroceras*, have no independent existence, because single individuals possess the distinguishing characters of all three genera combined. The fact that these genera were not inde-

[1] Report on the Geology and Resources of the Black Hills of Dakota. With atlas. By Henry Newton, E.M., and Walter P. Jenney, E.M., Washington, 1880. Palæontology by R. P. Whitfield.

pendent was suspected by the author when at work upon the Newton material twenty-five years ago, and the compound character of some ammonites has been stated by Professor Alpheus Hyatt, but these seem to be the first specimens to be described which actually show the combination in a single individual.

Professor **Whitfield's** second paper described a new Teredo-like shell from the Laramie group of eastern Wyoming, collected by Mr. Barnum Brown, of the American Museum. This teredo, to which the author has given the name *Xylophomya laramiensis*, is more than an inch in diameter, thus ranking as the largest species of the family known.

These two papers may be found in full in the current volume (Vol. XVI) of the Bulletin of the American Museum of Natural History.

The third paper of the evening was by Professor **James Douglas**, and gave a description, illustrated by topographic map and numerous lantern slides, of the famous Rio Tinto group of the copper mines of the Huelva district in Spain. These mines have been worked from time immemorial, the earliest knowledge of them dating from the Phœnicians, who occupied the country in the eleventh century, B. C. The Romans also obtained a large amount of copper from these deposits, and it is an interesting fact that the slags which they left are purer, that is, freer from copper, than those which are made there to-day. The ore is a copper-bearing pyrite, carrying some silica. The copper-bearing portions run irregularly through the iron pyrites, and the Rio Tinto Company has removed millions of tons of forty-two per cent. iron ore in getting at its copper ore. The iron ore is not profitable at the present time, although it may become so in the distant future. There are some remains of the workings of the ancients here. At Tharsis in particular the old shafts are very peculiarly constructed, one at least being spiral, to enable the miners to carry the ore on their backs. Shelves are excavated at intervals in the walls of the shaft to enable the men to rest their loads on their weary journey to the surface.

The mines are worked now as open-air diggings in circular terraces. They produce about two million tons of ore per year, and it is estimated that there are one hundred and sixty million tons in sight. Some silver-bearing galena is associated with the copper ore. The old-fashioned method of roasting the ore in heaps was kept up until 1893, but the ore is now leached by means of water. This is a long process, requiring four years for its thorough completion, but the copper is leached out so that less than one fourth of one per cent. is left in the tailings. The great bulk of the world's supply of sulphuric acid is obtained from the Rio Tinto pyrite, which is shipped all over the world for the purpose of manufacturing the acid. Five hundred thousand tons per year are utilized in this way.

The paper was discussed by Dr. Julien and Mr. Howe, and the section passed a hearty vote of thanks to Professor Douglas for his kindness in giving the paper.

EDMUND O. HOVEY,
*Secretary.*

## SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

JANUARY 27, 1902.

Section met at 8:30 P. M., Professor Farrand presiding. The minutes of the last meeting of Section were read and approved.

After opening the meeting, the chairman called on General James Grant Wilson to preside.

The following program was then offered:

**F. S. Dellenbaugh,** THE LOCATION OF HISTORIC TOWNS AND "NATIONS" OF NEW MEXICO PRIOR TO 1630.

**Harlan I. Smith,** A RECENTLY DISCOVERED EARTHWORK IN OGEMAW COUNTY, MICHIGAN.

**John R. Swanton,** MYTHOLOGY AND ORIGIN OF THE HAIDA INDIANS.

SUMMARY OF PAPERS.

Mr. **F. S. Dellenbaugh** explained his understanding of the location of the historic towns and "nations" of the Rio Grande valley in New Mexico prior to 1630. This differs radically

and entirely from the present accepted arrangement. He maintains that the location of Tiguex, rather than Cibola, is the key to the correct solution of this problem, and from strong evidence derived from Benavides, Espejo, Castañeda and others, he locates Tiguex near San Antonio station. The site at Bernalillo, for this central town, so long advocated by Bandelier and his followers, he declares is impossible. With Tiguex at San Antonio station, the famous "Seven Cities of Cibola," which Bandelier placed on the site of modern Zuñi, are thrown instead into southwestern New Mexico, either on the Gila near Old Camp Vincent, or Old Fort West, or between these and the Florida Mountains, with the balance in favor of a site on the Gila. Cicuyé, instead of being at Pecos, was apparently a Tompiras town, either what has been erroneously called *Gran Quivira* or some village of that locality. The Braba of Coronado would fall in the vicinity of the present Cochiti, instead of at Taos, and Tusayan instead of being at the Moki towns, would fall in its position 20 leagues (50 or 60 miles) northwest of the position of Cibola.

Mr. **Harlan I. Smith** presented a paper on the "Hauptman Earthwork," in Ogemaw County, Michigan. The discovery of this earthwork was first announced by him in *Science*, June 21, 1901 (p. 991). Personal observation in July enabled him to correct its location somewhat. It is on Section 33 or 34, or both, T. 22, N. (instead of 21), R. 1, E. It was found to lie in a lumbered pine area, and, unlike most such earthworks, far from any watercourse. It is covered by dense undergrowth and fallen timber. It is composed of a rounded embankment of earth, about two feet high and twelve feet wide, encircling an area about 197 by 177 feet; outside this is a ditch, two feet deep, six feet wide at the top, but narrowing towards the bottom. Signs of another embankment were seen outside the ditch, and within the enclosed area were several hummocks which may prove to be mounds or similar works. There are three openings in the embankment. The antiquity of the work is indicated by the presence of large pine stumps on the embankment and in the ditch; the largest stump measured thirteen feet four inches in circumference.

An effort is being made to have this ancient work enclosed in a state, county or township park. The land, now worth perhaps less than $10 an acre, can easily be secured. If neglected, the road to be built on the line between sections 33 and 34 will probably destroy the work.

Dr. **John R. Swanton** reported some results of his investigations into the mythology and origin of the Haida Indians of northern British Columbia. The whole Haida people is divided into two clans, Raven and Eagle, each of which is strictly exogamic with descent in the female line, and has its own crests, its own names, its independent traditional centers of origin. Each is subdivided into a number of families. The Raven clan traces its origin from a single legendary ancestress, who is reputed to have emerged from the waters with the Haida island. Some families of that clan, however, trace their descent from other sources. The Eagle clan has much less traditional unity of origin, and there are certain indications in the tradition that this clan is of foreign origin or at least has received considerable admixture of foreign blood. One important fact that seems to point to the Raven clan as the indigenous element is the great preponderance of Ravens among the supernatural beings of the island.

R. S. Woodworth,
*Secretary.*

## BUSINESS MEETING.

February 3, 1902.

Academy met at 8:20 P. M., President Woodward presiding.

The Secretary reported from the Council as follows:

That the Council had nominated the three following Honorary Members, to be voted upon at the forthcoming Annual Meeting.

James Dewar, M.A., LL.D., F.R.S., Jacksonian Professor of Experimental Philosophy, University of Cambridge, England.

William James, M.D., LL.D., Ph.D., Litt.D., Professor of Philosophy, Harvard University, Cambridge, Mass.

Wilhelm Wundt, Ph.D., M.D., Professor of Philosophy, University of Leipzig, Germany.

That the Council had voted to nominate no corresponding members.

That the Council had voted to nominate the following Fellows to be voted upon at the Annual Meeting:

Maurice A. Bigelow, Herman C. Bumpus, O. B. Hay, E. O. Hovey, W. D. Matthew, S. J. Meltzer.

The Recording Secretary read the list of nominations of Officers prepared by the Council, and announced that it would be mailed to members of the Academy two weeks before the Annual Meeting.

The proposed bill for amending the Charter, which is herewith appended[1] was submitted by the Council, with the recommendation from the Council that it be approved by the Academy, and that if approved the Academy authorize the Charter Revision Committee to take such steps as are necessary to have the bill enacted into law.

It was voted to approve the bill, and to give the Charter Revision Committee the authorization requested.

Adjourned.

RICHARD E. DODGE,
*Recording Secretary.*

## SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

FEBRUARY 3, 1902.

Section met at 8:40 P. M., Professor Hallock presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered:

**Mr. G. B. Pegram,** EXPERIMENTAL METHODS OF STUDYING RADIO-ACTIVITY.

SUMMARY OF PAPERS.

The paper of the evening consisted of a description of the methods which have been employed in studying radio-active substances, and also a brief summary of the more important results which have been obtained.

[1] See Appendix.

The discussion of the paper was confined chiefly to questions regarding these methods and results.

Section adjourned.

F. L. Tufts,
*Secretary.*

## SECTION OF BIOLOGY.

February 10, 1902.

Section met at 8:15 P. M., Professor Stratford presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered:

**W. B. Scott,** The Origin and Development of South American Mammals.

Summary of Papers.

Professor **Scott** began by expressing his great obligation to Dr. F. Ameghino, as also to Dr. Moreno, Director, and to the Curators of the La Plata Museum, for their kindness in giving him the freest use of their collections, and enabling him to examine all the types of the Santa Cruz mammals.

The fauna of every continent is made up of two elements, the indigenous forms which were developed in that continent, and the immigrants from other regions. In South America this distinction is easy to draw, because of the remarkable series of Tertiary deposits which are wonderfully rich in well-preserved fossils. The Santa Cruz beds, which are referable to the lower Miocene, contain an assemblage of mammals altogether different from those of the northern hemisphere. The fauna consists of Primates and Insectivora, very scantily represented, very numerous Rodents (though all referable to the Hystricomorphs), Marsupials, Edentates, and the peculiar South American hoofed animals. The Edentates of this period represent the Gravigrada, Glyptodonts, and Armadillos, but no members of the true sloths or Anteaters have yet been found, a lack of which is probably due to climatic conditions. The Gravigrada, which are very abundant, have forerunners of all the great Pleistocene groups, but are, of course, much less specialized and are rel-

atively small in size. The Glyptodonts, though numerous and well preserved, are not so easily brought into relations with the later genera of the same group.

The paper concluded with a brief examination of the remarkable Ungulates, all of which are peculiar to South America and especial attention was called to Ameghino's discovery, yet unpublished, that in *Nesodon* there are three sets of functional incisors and canines. Incredible as such an observation may be, it seems to be well established.

HENRY E. CRAMPTON,
*Secretary.*

## SECTION OF GEOLOGY AND MINERALOGY.

FEBRUARY 17, 1902.

Section met at 8:30 P. M., Dr. Alexis A. Julien presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered:

**O. P. Hay,** THE SNOUT-FISHES OF KANSAS.

**A. A. Julien,** THE EFFECT OF VARIOUS KINDS OF HONE-STONES ON THE CUTTING EDGE OF TOOLS.

### SUMMARY OF PAPERS.

Dr. **O. P. Hay** presented a brief history of our knowledge of the genus *Protosphyræna* and a statement showing what portions of the skeleton were still unknown. The parts which are best known are the skull, especially the elongated snout, the jaws, the shoulder-girdle and the caudal and the pectoral fins. These parts have seldom been found associated, and there have been established three series of species, one on the teeth, another on the snout and a third on the fins. It is certain that, as new collections are made and studied, some of these new species will be reduced to synonymy. The author pointed out several errors on the part of writers in the interpretation of different elements of the skeleton and illustrated his points by means of specimens.

In his impromptu paper Dr. **A. A. Julien** gave a summary of

the results of some recent investigations he had made on a series of chisels which had been sharpened on several kinds of hones. In the course of his remarks he said that the quality of a hone depended on the size and shape of its component particles, and upon the cement joining the whole together. An exception was noted in the case of the novaculites from Arkansas, in which the honing quality is due to the sharp edges of minute cavities left by the solution of calcite; and in the case of Turkey-stone, in which the honing quality is due to veinlets of quartz intersecting a rock which has been formed by silica replacing a granular limestone. A microscopic study shows that the edge of a tool is not regularly serrated, part of it being smooth and part undulatory. Viewed on edge the sharpest tools are practically straight, while the others are more or less irregularly wavy. Viewed in the cross-section, a fine edge is seen to be a perfect wedge, while the duller tools show a minute shoulder.

EDMUND O. HOVEY,
*Secretary.*

## ANNUAL MEETING.

FEBRUARY 24, 1902.

The Academy met for the Annual Meeting at 8:15, President Woodward in the chair.

Reports of the officers for the past year were called for and presented in the following order:

The Recording Secretary read a report from the Corresponding Secretary to the effect that no correspondence with Honorary or Corresponding Members had been conducted during the year.

The report of the Recording Secretary, filed herewith, was read.

The accompanying report of the Treasurer was read and referred to the Finance Committee for auditing.

The accompanying reports of the Librarian and Editor were read.

The following nominations for Honorary Members, selected by the Council according to the By-Laws, were read, and the

Secretary was empowered to cast an affirmative ballot of the Academy therefor, which was done.

James Dewar, M.A., LL.D., F.R.S., Jacksonian Professor of Experimental Philosophy, University of Cambridge, England, 21 Albemarle St., London, England.

William James, M.D., LL.D., Ph.D., Litt.D., Professor of Philosophy, Harvard University, Cambridge, Mass.

Wilhelm Wundt, Ph.D., M.D., Professor of Psychology, Leipzig, Germany.

The following list of Fellows, nominated by the Council according to the By-Laws, was read, and the Secretary was empowered to cast the affirmative ballot of the Academy therefor, which was done.

Maurice A. Bigelow.

Hermon C. Bumpus.

O. P. Hay.

E. O. Hovey.

W. D. Matthew.

S. J. Meltzer.

The President then appointed Professors Charles Lane Poor and J. K. Rees as tellers; ballots were distributed, votes received and counted, and the following list of officers elected:

President: J. McKeen Cattell.

First Vice-President: Nathaniel L. Britton.

Second Vice-President: Richard E. Dodge.

Corresponding Secretary: Bashford Dean.

Recording Secretary: Henry E. Crampton.

Treasurer: Charles F. Cox.

Librarian: Livingston Farrand.

Councillors: Franz Boas, Hermon C. Bumpus, D. W. Hering, Frederic S. Lee, Charles Lane Poor, L. M. Underwood.

Curators: Harrison G. Dyar, Alexis A. Julien, George F. Kunz, Louis H. Laudy, E. G. Love.

Finance Committee: John H. Caswell, John H. Hinton, C. A. Post.

Three nominations for resident membership were read and referred to the Council according to the By-Laws.

The President and Recording Secretary elect then took the Chair, and President Woodward delivered his Annual Address, entitled "Measurement and Calculation."

At the close of the address a vote of thanks to the retiring President was moved by ex-President Osborn, and carried.

Adjourned.

Richard E. Dodge,
*Recording Secretary.*

## REPORT OF THE RECORDING SECRETARY.

During the last academy year the Council and the several sections of the Academy have held their customary meetings, and the academy work has progressed in many ways favorably along the usual lines.

At the meetings there have been 68 papers presented, divided as follows:

| | |
|---|---|
| Anthropology 7. | Palæontology 6. |
| Archæology 3. | Photography 1. |
| Astronomy 4. | Physics 8. |
| Botany 1. | Physiography 4. |
| Geology 9. | Physiology 2. |
| Mechanics 3 | Psychology 8. |
| Miscellaneous 3. | Zoölogy 9. |

There are at present 298 Resident Members, 92 Fellows, and the election of six Fellows is pending.

At the May meeting, on recommendation of the Council, Dr. Franz von Leydig, of Würzburg, Germany, was elected an Honorary Member, and in October, the Executive Committee of the Council sent a letter of congratulation to Dr. Rudolf Virchow on the occasion of his eightieth birthday. The Academy has lost during the year one of its leading workers, Dr. Theodore Greeley White, who died in July; a suitable minute concerning Dr. White is printed in the Records for the year. Twelve members of the Academy have been dropped from the rolls for non-payment of dues.

The leading task that the Council has had to consider for the year has been that of modifying the Constitution and By-Laws to suit existing conditions. It was found necessary, in order to bring this about, to have the charter revised, and by vote of the Academy, February 3, a committee of the Council was authorized to have a bill presented to the Assembly and Senate of New York to this end. Word has just come of the passage of the bill by both members of the legislative body. In accordance with the bill a new Constitution must be adopted by the Academy within three months, and a committee is already at work on this problem.

The other serious matter now under discussion by the Council is the question of the method of printing the short papers of the Academy, which will go into effect at the beginning of the current volume of the ANNALS.

Respectfully submitted,

RICHARD E. DODGE,
*Recording Secretary.*

## REPORT OF THE TREASURER.

### RECEIPTS.

| | | |
|---|---|---|
| Balance as per last Annual Report... | | $4,337.20 |
| Mortgage on 113th St. property paid off | | 9,000.00 |
| Income, Permanent Fund............ | $489.70 | |
| " Audubon Fund............. | 47.95 | |
| " Publication Fund........... | 98.45 | 636.10 |
| Life Membership Fee............... | | 100.00 |
| Initiation Fees..................... | | 25.00 |
| Annual Dues, 1898................ | 10.00 | |
| " 1899................ | 50.00 | |
| " 1900................ | 110.00 | |
| " 1901................ | 2,225.00 | |
| " 1902................ | 30.00 | 2,425.00 |
| | | $16,523.30 |

### Disbursements.

| | | | |
|---|---|---|---|
| Invested in Bond and Mortgage @ 5 % on 205 St. Ann's Avenue........ | | 12,000.00 | |
| Publication of Annals...... | $1,499.12 | | |
| Less Sales............. | 247.86 | 1,251.26 | |
| Publication of Memoirs..... | 530.97 | | |
| Less Sales............. | 33.22 | 497.75 | |
| Rent of Rooms.......... ........ | | 325.00 | |
| Dues to Scientific Alliance........... | | 50.12 | |
| Expenses of Treasurer.............. | | 31.78 | |
| " Librarian .............. | | 191.23 | |
| " Recording Secretary ..... | | 211.94 | |
| General Expenses.................. | | 51.90 | |
| Lectures ........................ | | 34.25 | $14.645.23 |
| Balance, Cash on Hand......... | | | 1,878.07 |

### Balance Sheet.

February 24, 1902.

| | Dr. | Cr. |
|---|---|---|
| Permanent Fund................ | | $10,551.43 |
| Publication Fund................ | | 1,823.69 |
| Audubon Fund................. | | 1,897.25 |
| Invested in Bond and Mortgage at 5 per cent.................. | $12,000.00 | |
| Income Account (Due Permanent Funds) ................... | 394.30 | |
| Cash on Hand................. | 1,878.07 | |
| | $14,272.37 | $14,272.37 |

Charles F. Cox,
*Treasurer.*

## REPORT OF THE LIBRARIAN.

The work in the Library during the past year has been directed toward clearing up the accumulations in exchanges during the period of financial stress through which the Academy has been passing; and the Librarian is glad to be able to state that through the energy of the present assistant, Mr. W. M. Erb, all material up to date is now sorted, catalogued and filed on the shelves and open to reference to members of the Academy.

The great need of the Library is still, as it has been for a number of years past, an appropriation for the binding of books. Hundreds of volumes of periodicals have now accumulated and while every effort is made to preserve them intact considerable injury and loss is unavoidable. A second need is adequate cataloguing by expert hands. The usefulness of the Library would be much increased if this could be provided. With the limited appropriation at present at the disposal of the Librarian it has seemed wiser to concentrate the energy upon keeping the accessions in order rather than to divert any portion of the funds to the two purposes suggested. The same policy will doubtless be pursued during the coming year.

Respectfully submitted,

LIVINGSTON FARRAND,
*Librarian.*

## REPORT OF THE EDITOR.

Volume XIII of the ANNALS, Parts 2 and 3, comprising four papers, together with the Records of the Meetings of the Academy, from January, 1900, to December, 1900, have been printed and distributed. This completes Volume XIII of the ANNALS, which consists of seven papers, together with the Records forming a volume of 542 pages and 16 plates.

Volume XIV of the ANNALS, Part 1, has also been printed and distributed, and this Part consists of four papers of 84 pages and 5 plates. Volume XIV, Part 2, containing the Records of the Meetings of the Academy for the year January, 1901,

to December, 1901, is now in press, and will be distributed to the members within a very short time.

Volume II, Part 3, of the *Memoirs*, entitled "Palæontological Notes," by Bashford Dean, 4to, pages 87–123; plates 3 to 8, has also been printed and distributed. This *Memoir* was in part paid for out of the Audubon Fund.

When the Editor was appointed, in December, 1900, the funds of the Academy available for publication had been exhausted, and the year was begun with a large deficit. During the year the accounts have been straightened out, the deficit met, and the year will close with practically a clean balance sheet.

Respectfully submitted,

CHARLES LANE POOR,
*Editor.*

## PRESIDENT'S ADDRESS.

### MEASUREMENT AND CALCULATION.

In my address of a year ago I sought, in a summary way, and by concrete illustration, to indicate how science originates in and advances with observation and experiment. I would now invite your attention to a similar consideration of the rôle which measurement and calculation play in the higher developments of science.

All sciences are at first qualitative. They pass in their growth from the fact-gathering stage of unrelated qualities to the orderly stage of related qualities and thence upward to the stage of quantitative correlation under theory. Such, at any rate, has been the course of all sciences hitherto developed, and it seems safe to predict that such will be the course of those which may arise in the future. The recognition of this fact is of prime importance. It helps us to understand the great relative diversity in perfection among the sciences; it affords a basis for rational optimism with respect to the continued progress of science; and it ought to make the specialists of the older sciences less contemptuous than they sometimes are in their attitude toward the newer ones which have not yet passed the "rock-naming and bug-hunting stage."

Whenever a quantitative relation between the factors of phenomena is observed, then measurements may be made in response to the question, What is the magnitude of the relation, if constant, or what are the extent and law of variation of the relation if it is not constant? When the law of relation is known, related quantities are subject to calculation, the measured values of some of them sufficing, through computation, to give the values of the others. All calculations, therefore, presuppose a knowledge of the laws of connection of related quantities or quantitative theories of the phenomena considered.

Measurements and calculations are of all grades of definiteness, ranging from the smallest probabilities of the doctrine of chances up to the rigorous certainties of mathematical deduction. Thus the degree of precision attainable in the measured and computed quantities of a science is commonly taken as a gauge of its perfection. But it would be a mistake to infer complete perfection from the precision attainable in one or more branches of science. Astronomy, for example, is a marvelously perfect science in certain of its branches, but nevertheless some of its fundamental constants, notably the gravitation constant and the aberration constant, are known with only a low degree of precision.[1] Whether any quantity may be

[1] The gravitation constant is the factor by which the product of two masses divided by the square of their distance asunder must be multiplied in order to express the force exerted by those masses on one another. Thus, if $m_1$ and $m_2$ denote two masses, $s$ their distance asunder, $F$ the force of attraction between them, and $k$ the gravitation constant, then

$$F = k\frac{m_1 m_2}{s^2}.$$

It should be remarked that $k$ is not a mere numeral, as many eminent writers on the law of gravitation would seem to imply, but that it is the cube of a distance divided by the product of a mass and the square of a time; or that its dimensions are shown by the exponents in $(L^{+3}M^{-1}T^{-2})$ if $L$, $M$, $T$ denote the units of length, mass and time respectively.

It should be remarked also that the above expression of Newton's law of gravitation lacks the precision essential for mathematical calculations. To make the statement definite and general, $m_1$ and $m_2$ must be regarded as infinitesimals, so that the resultant attraction between two finite bodies requires, in general, a summation, or integration, for its exact expression. A widespread error exists in the notion that the above equation is exact if the distance $s$ is the distance between the

measured or calculated with precision depends, in general, on the degree of complication of its connections with other quantities, and on the applicability of methods already applied in the determination of other quantities. Frequently, a quantity may be measured directly; but it oftener happens, either by reason of the inapplicability or of the disadvantage of a direct method, that resort is had to an indirect method.

It is a remarkable fact, illustrating the essential unity which pervades the apparent diversity of nature, that all of the numerous quantities with which physical science has to deal may be expressed in terms of a certain very limited number of arbitrarily chosen quantities, or units. The units most commonly used, and those which seem best suited to the present requirements of science, are the units of length, mass and time. All other quantities, however complex, may be expressed readily in terms of these arbitrarily assumed fundamental quantities. It is by no means certain, however, that these units will best satisfy the requirements of science in the future. On the contrary, it seems rather probable that advancing knowledge will find some other system of units preferable, if it does not find several different though interconvertible systems essential. We have, in fact, already attained two such diverse systems in the units of electromagnetic science.

The study of such systems by the aid of the theory of dimensions, which shows algebraically how the assumed units enter into more complex quantities, is very instructive, not only to the mathematical physicist, but to the general student of physical science.[1] To illustrate this idea by some simple examples, it is

centers of gravity of the masses. This is true, indeed, for the class of bodies called centrobaric, like homogeneous spheres; but masses in general are not centrobaric.

The gravitation constant is in C.G.S. units, about $667 \times 10^{-12}$, with some uncertainty in the last significant figure.

The aberration constant, which is (if it is nothing more than a kinematical quantity) the ratio of the velocity of the earth in its orbit to the velocity of light multiplied by the number of seconds in a radian, is about $20.5''$ with some uncertainty in the next significant figure.

[1] Designating the units of energy, length, mass and time by $E$, $L$, $M$, $T$ respectively, the dimensions of some of the most frequently used quantities in mechanics are shown in the following tables. In the first of these length, mass and

well known that all quantities used in rational mechanics are commonly expressed in terms of length, mass and time. But these quantities might be expressed equally well, so far as algebraical statement is concerned, in many other ways. Thus we might take energy as one of the fundamental quantities instead of either length, mass or time; in which case our mechanical

TABLE I.

| Quality. | Length Factor. | Mass Factor. | Time Factor. |
|---|---|---|---|
| Velocity | $L^{+1}$ | $M^{0}$ | $T^{-1}$ |
| Acceleration | $L^{+1}$ | $M^{0}$ | $T^{-2}$ |
| Force | $L^{+1}$ | $M^{+1}$ | $T^{-2}$ |
| Momentum | $L^{+1}$ | $M^{+1}$ | $T^{-1}$ |
| Energy | $L^{+2}$ | $M^{+1}$ | $T^{-2}$ |
| Power | $L^{+2}$ | $M^{+1}$ | $T^{-3}$ |

TABLE II.

| Quality. | Energy Factor. | Mass Factor. | Time Factor. |
|---|---|---|---|
| Velocity | $E^{+\frac{1}{2}}$ | $M^{-\frac{1}{2}}$ | $T^{0}$ |
| Acceleration | $E^{+\frac{1}{2}}$ | $M^{-\frac{1}{2}}$ | $T^{-1}$ |
| Force | $E^{+\frac{1}{2}}$ | $M^{+\frac{1}{2}}$ | $T^{-1}$ |
| Momentum | $E^{+\frac{1}{2}}$ | $M^{+\frac{1}{2}}$ | $T^{0}$ |
| Energy | $E^{+1}$ | $M^{0}$ | $T^{0}$ |
| Power | $E^{+1}$ | $M^{0}$ | $T^{-1}$ |

TABLE III.

| Quality. | Energy Factor. | Length Factor. | Mass Factor. |
|---|---|---|---|
| Velocity | $E^{+\frac{1}{2}}$ | $L^{0}$ | $M^{-\frac{1}{2}}$ |
| Acceleration | $E^{+1}$ | $L^{-1}$ | $M^{-1}$ |
| Force | $E^{+1}$ | $L^{-1}$ | $M^{0}$ |
| Momentum | $E^{+\frac{1}{2}}$ | $L^{0}$ | $M^{+\frac{1}{2}}$ |
| Energy | $E^{+1}$ | $L^{0}$ | $M^{0}$ |
| Power | $E^{+\frac{3}{2}}$ | $L^{-1}$ | $M^{-\frac{1}{2}}$ |

quantities would be expressed in terms of energy, length and mass; or of energy, length and time; or of energy, mass and time. A consideration of these simple systems shows us, among other things, that rational mechanics might have been developed along

time appear explicitly; in the second length does not appear explicitly; and in the last, time does not appear explicitly. A glance at the exponents (dimensions) of the symbols shows clearly how definite the meanings of the terms force, energy, power, etc., may be in comparison with the utter ambiguity attaching to them in common parlance.

lines of thought very different from the lines followed by our predecessors; and the fact that we do not visualize equally clearly all these systems shows the experience of humanity with physical phenomena has been extremely limited. Most curious and instructive are the system in which length does not appear explicitly and the system in which time does not appear explicitly. May we not see in these systems opportunities respectively for the development of those individuals of our race who seem to possess no realization of distance or no conception of time?

Confining attention to the simpler and more familiar units of length, mass, and time, and to a few of the more complex quantities expressed thereby, let us first consider briefly the present status of these fundamental units and the possibility of maintaining their invariability. The standards of length and mass which are now universally adopted in science are the meter and the kilogram respectively, carefully intercompared copies, or "prototypes," of which have been distributed by the international bureau of standards to the nations contributing to the cost thereof. The United States possesses two copies of each of these prototypes, and they are, as a matter of fact, our effective working standards, even for the production of standard yards and pounds. It is to be hoped, therefore, that the end of the barbaric system of "weights and measures," we have inherited from an unscientific ancestry, is near at hand, and this not so much in the interest of men of science as in the interests of those less well fitted to struggle with the ingenious intricacies of the British system.

These prototype meters and kilograms are known in terms of the adopted standards, and hence in terms of one another, with a degree of precision which verges close to the limits of the constancy of matter itself. Thus the lengths of the meters are known with an uncertainty expressed by a probable error of only one part in five millions. This degree of refinement corresponds to about one hundredth of an inch in a mile, or to about nineteen miles in the mean distance of the earth from the sun. But this admirable precision is greatly surpassed by that of the kilograms, whose uncertainty falls to one part in five hun-

dred millions. It is well known, of course, that the operation of weighing by means of the balance secures a precision superior to that of every other species of physical measurement; but it is not easy to visualize directly the five-hundred-millionth part of a kilogram. One may get a tolerably definite idea of this magnitude, however, by observing that with the degree of precision in question it would be essential in comparing two kilogram masses to keep the pans of the balance closely at the same level, for a centimeter difference in their altitudes would be appreciable by reason of the variation of the attraction of the earth with distance from its center.[1]

For present purposes, therefore, our standards of length and mass leave little, if anything, to be desired. But it is a matter of great importance to the future progress of science that these standards be preserved for an indefinitely long period; and although such a contingency seems remote enough now, one can hardly suppress the query as to what would happen to us if our standards should be lost, or if they should unexpectedly prove unstable with the lapse of time. It is quite certain that our standard of length could be recovered with a high degree of precision if such a calamity should befall us during the next ten thousand, or possibly during the next hundred thousand years. Numerous bars of other metals than the alloy used in the construction of the prototype meters are known in terms of the latter. Many base lines scattered at widely separated points of the earth's surface are also known in terms of the meter with a precision of about one part in a million; and although the

[1] Denoting the mass of a kilogram by $m_1$ and the mass of the earth by $m_2$, the weight of $m_1$ by $w$, and the distance from the balance to earth's center by $s$ (since the earth is nearly centrobaric), the Newtonian law gives

$$w = k\frac{m_1 m_2}{s^2},$$

whence the relation of a small change $\Delta w$ in $w$ to the corresponding change $\Delta s$ in $s$ is expressed by

$$\frac{\Delta w}{w} = \mp 2\,\frac{\Delta s}{s}.$$

Since $\Delta w/w$ is here 1/500,000,000, and since $s$ is about 630,000,000 centimeters, $\Delta s = \mp 0.63$ centimeter.

foundations of the earth are far from stable, we can hardly expect such lines to become systematically shorter or longer in so brief a terrestrial interval as a million years. Better still, probably, is the check on the invariability of the meter afforded by Professor Michelson's measurement of it in terms of the wave-lengths of particular rays emitted by the metal cadmium.[1] In this, apparently, we have a cosmic standard, although it remains to be proved that the wave-lengths used will remain invariable in the unexplored parts of the universe into which we are journeying along with the solar system at the rate of some kilometers per second.

Our standard of mass is likewise connected directly with various masses which may serve as checks on its stability, and indirectly with the masses of definite volumes of many substances. It is especially well known in terms of the mass of a cubic decimeter of water at a standard temperature. It is less definitely known in terms of the atomic masses of the so-called elements, and it is roughly known in terms of the enormous though slowly varying mass of the earth.[2] But, on the whole, our standard

[1] See Tome XI, *Travaux et Mémoires du Bureau International des Poids et Mesures*, Paris, 1895. It is remarkable that the ratios of the three wave-lengths used to the meter were measured with a precision requiring seven significant figures, the uncertainty amounting to a few units only in the last figure. Thus the values of the wave-lengths used (designated as red, green and blue respectively) are as follows, in microns, or millionths of a meter:

0.643,847,2,
0.508,582,4,
0.479,991,1.

[2] If we could measure the gravitation constant with a precision extending to five significant figures, the mass of the earth would at once become known to the same degree of precision, provided only that the law of gravitation is exact to the same number of figures. For I have shown that the product of that constant and the mean density of the earth is known with a precision expressed by five significant figures. Thus, calling the gravitation constant $k$ and the mean density of the earth $\rho$,

$$k\rho = 36{,}797 \times 10^{-11} / (\text{second})^2.$$

This relation may be otherwise expressed by the following theorem: Let $\tau$ be the periodic time of an infinitesimal satellite which would revolve about the earth close to the equator (assuming no atmospheric resistance). Then the theorem asserts that

$$k\rho\tau^2 = 3\pi$$

where $\pi$ is the ratio of the circumference to the diameter of a circle. The value of $\tau$ is 1 hour, 24 minutes, and 20.9 seconds. See *Astronomical Journal*, Vol. XVIII., No. 16.

of mass must be regarded as less secure than our standard of length, although the prototype kilograms are less likely to change in mass with the lapse of time than the prototype meters are to change in length ; for while such a general variation in volume as is known to occur in metals, especially alloys, need not affect the former, it would almost certainly affect the latter.

Our unit of time is also known with a definiteness that meets in most cases the highest demands of science at the present epoch. The period of rotation of the earth, or the sidereal day, is the standard interval of time, though it has been found convenient for many purposes to use the shorter interval of a mean solar second, of which there are 86,164.1 in a sidereal day. That the earth rotates with wonderful regularity is a fact of the highest importance to science. Without that regularity the development of sidereal and planetary astronomy, with all they have entailed, would have been impossible except by the discovery of some other equally trustworthy timekeeper. But the laws of mechanics, which show us plainly why the earth rotates with such remarkable regularity, also show us that its period of rotation is subject to sources of disturbance, some tending to increase and some tending to decrease that period, whose effects, though too minute to be appreciable in such intervals as are known to human history, must certainly become considerable in the course of terrestrial history. Thus, the contraction of the earth due to secular loss of heat tends to shorten the day, while accumulations of meteoric dust and tidal friction tend to lengthen it.[1] There exists also a graver source of disturbance

[1] I have discussed the effects of secular cooling and meteoric dust on the length of the day in a paper published in the *Astronomical Journal*, Vol. XXI., No. 22, July, 1901. From this paper it appears that the change in length of the day from secular cooling cannot be perceptible during any such brief interval as that of human history (twenty centuries, say); but that in the course of complete cooling, or in a million million years, say, the change in length of the day may amount to as much as six per cent. of its original length.

From the same paper it appears that accumulations of meteoric dust will only begin to be perceptible in their effects on the length of the day when the process of secular cooling has been substantially completed. In a subsequent number of the *Astronomical Journal* (Vol. XXII., No. 11), Dr. G. Johnstone Stoney has shown that if the compression produced by a layer of meteoric dust is taken into account the effect will be still less than that just indicated.

in the slow rising and sinking of the crust of the earth in different latitudes so often pointed out by geologists. Such movements are only partly compensating in their effects on the day, and it seems highly probable that they may cause irregularities amounting to a few seconds in a century without entailing any noteworthy fluctuations of the relative positions of the land and sea.[1]

It appears, then, that our time unit is the least stable of the three fundamental units and hence the most in need of checks on its stability. Various other standards of time have been proposed, but none of them meets the requisites of permanency and availability. The interests of astronomical science especially demand that efforts be made to find in the solar system some better timekeeper than the earth. Possibly the fifth satellite of Jupiter may serve as a control on the constancy of rotation of the earth.

Turning now to a consideration of the more complex quantities which are expressed in terms of length, mass and time, we enter the boundless fields of physical science in which measurement and calculation have revealed to us all ranges of magnitudes from the vanishingly small to the indefinitely large. It is in these fields that we learn something definite concerning the limitations of our senses; for while measurements alone carry us but a little way along lines of research, calculation discloses not only the unseen, but also, in many cases, phenomena which are quite beyond the reach of any direct sense perception.[2]

To begin with quantities near the lower limit of determination, think, for a moment, what is going on in the air which for the present is the main medium of communication between us. No one has ever seen the particles of the atmosphere in the sense that we have all seen the particles, or corpuscles, of the blood. But we probably know more about the molecules of gases than

[1] See "Mathematical and Physical Papers of Lord Kelvin," Vol. III, pp. 333–335, Cambridge University Press, London, 1890.

[2] The reader may be referred to a very instructive paper by Dr. G. Johnstone Stoney, entitled "Survey of that Part of the Range of Nature's Operations which Man is Competent to Study." *Scientific Proceedings of the Royal Dublin Society*, Vol. IX, No. 13; *Philosophical Magazine*, Fifth Series, No. 294, November, 1899; published also in *Report of Smithsonian Institution* for 1899.

we do about blood corpuscles. By actual count it is known that there are four to six millions of the latter in a cubic millimeter; and with equal definiteness calculation shows us that there are about a million million million molecules in a cubic millimeter of the air around us. Notwithstanding this apparently crowded assemblage, the individual molecules move about in the liveliest manner, their average speed being about five hundred meters per second, and this in spite of the fact that the average length of an unimpeded journey is barely visible by the aid of the best microscopes. Each molecule must therefore collide with its neighbors astonishingly often, the encounters occurring, in fact, about five thousand million times per second.[1]

More surprising still than the properties of assemblages of molecules forming gases are the properties of the individual molecules, especially when they are made up of two or more atoms. Such miniature systems, comparable, probably, in complexity with the Martian and Jovian subsystems of the solar system, exhibit degrees of constancy which rival the invariableness of the fixed stars themselves. This is particularly the case with their rates of vibration as disclosed by the spectroscope. These rates afford one of the most delicate tests of the properties of matter, whether it is found on the earth or on the most distant star; and yet the vibrations, which recur with a regularity equal to, if not surpassing, the regularity of the rotation of the earth, are executed at the rate of some hundreds of millions of millions per second.[2] Herein, perhaps, we may find a cosmic unit of time as well as a cosmic unit of distance, though both appear to be inconveniently small for terrestrial purposes.

But the smaller bodies of the universe do not end with mole-

[1] See, for example, "The Kinetic Theory of Gases," by Dr. Oskar Emil Meyer, translated by Robert E. Baynes, Longmans, Green & Co., New York, 1899.

[2] The number of vibrations per second corresponding to any given wave-length of light may be easily computed. For the velocity of light is about 300,000 kilometers, or $3 \times 10^{14}$ microns per second, and this divided by the wave-length in question gives the number of vibrations per second. Thus the average wave-length of the cadmium rays used by Professor Michelson (cited above) is about half a micron. The material sources of these rays must vibrate, therefore, about six hundred million million times per second.

cules and atoms of gases. Recent investigations point to the conclusion that there is another order of bodies of much smaller dimensions and possessing still more wonderful properties. These have been called corpuscles.[1] Their density is only about one thousandth as great as that of the lightest gas, hydrogen; they are freely given off by several of the so-called radioactive substances; and they move about with speeds of the same order as the velocity of light. It appears not improbable that they play a most important rôle in cosmic as well as in terrestrial physics, and the amount of attention being given to them justifies the hope that their study may illuminate many obscure corners in the realm of molecular science.

Passing per saltum from the smallest measurable and calculable quantities to those with which we have an every-day familiarity, I would direct your attention to the great number of articles of commerce which are now weighed, measured and rated with precision and sold at a cost which, a half century ago, would have been thought quite impossible. Standard yards, meters, pounds and kilograms, and pocket time-pieces that will run within a few seconds per day, are available at prices within the reach of all who need them. Screws and screw gauges which will easily measure a hundredth of a millimeter (or four ten-thousandths of an inch) are articles of trade; beautifully true spheres of steel or bronze may be had for a few cents each; helical springs of the finest steel and of remarkable uniformity are sold for a dollar a dozen; while articles like wire, tubing, sheet metal, and an indefinite variety of tools and machinery are made with a degree of perfection and at a cheapness of cost which would have been regarded as quite unattainable by the

[1] See a paper by Professor J. J. Thomson, "On Bodies Smaller Than Atoms," *Popular Science Monthly*, August, 1901.

See also a paper by Professor John Cox on "Comets' Tails, the Corona and the Aurora Borealis," *Popular Science Monthly*, January, 1902.

A fact of great interest in connection with the "corpuscles" considered in these two papers is the repulsion of light impinging on bodies, the amount of which has been actually measured recently by several observers. This repulsion between the sun and the earth is very great, amounting to about a hundred million million dynes; but the gravitational attraction between these bodies is about forty million million times as great as that repulsion.

founders, for example, of the New York Academy of Sciences. The ready availability of, and the constant demand for, all these products to meet the daily needs of the complex civilization of our time affords a sufficient answer to him who would question the efforts spent in attaining those products or the efforts applied in subjecting new objects of study to the rigorous tests of measurement and calculation.

But the principles of measurement and calculation are not limited in their application to external objects, or to the properties of what we are sometimes pleased to call "gross matter." They apply equally aptly in many ways to man himself, and it is clear that with advancing civilization we may confidently expect such application to be greatly extended. While we have not yet attained formulas which will comprehend the vagaries of the individual, we have many formulas which will accurately express the resultant of those vagaries as manifested in racial types. A life insurance company, for example, may not assert at the beginning of a year that any individual of ten thousand men of the same class will die within the year, but it may assert with practical certainty that a definite number of this class will die within the year. Such "facts and figures" are trite enough, of course, but what we commonly fail to see and appreciate is the solid basis on which they rest, and how greatly it would be to our advantage to extend the same sort of reasoning that has built up great systems of fire and life insurance into other departments of human affairs. Most people, I fear we must infer, are like Thomas Carlyle, still scoffers at statistics, and few, even of the educated, have any adequate conception of the order which the principles of probability will bring out of the apparent disorder of statistical data.

Of the larger objects of the universe to which measurement and calculation have been applied with success, the earth easily surpasses all others in interest and importance. So great has been this success that one may assert that we know more of the earth than we do of any other body to which science has given attention. Its size, its shape, the amount and arrangement of its mass, its magnetic properties, its speeds of rotation and trans-

lation, its precession and nutation, and the lately discovered wabbling of its axis of rotation are all known with a definiteness which is truly surprising when one considers its magnitude and the degree of complexity of those properties. That the eight thousand miles in its diameter should be known within a few hundred feet, that the two hundred millions of square miles in its surface should be known within a few hundred square miles, or that the acceleration of gravity at any point on its surface should be known within a few millimeters per second per second, are results little short of marvelous when one reflects that they have all been attained within the brief interval of two hundred and fifty years. It would be quite wrong, however, to consider these achievements of geodesy as marvelous from the point of view of science. They are, rather, just such results as persistent scientific investigation has always produced, and such as we may safely predict will be uniformly produced by persistent scientific investigation in the future. The element of the marvelous comes in only when one takes account of the fact that these grand results were attained by a very small number of men, mostly members of academies, struggling, like our own, to maintain an existence, in whose work the general public took little interest, and whose names, even now, are much less known than the names of the obscure philosophers and the obscene poets of antiquity.

Geodesy is undoubtedly the most advanced of the sciences in which measurement and calculation have attained a high order of certainty. It has made modern commerce possible, and it seems destined to play a still more important rôle than it has hitherto in the advancement of terrestrial affairs. It has also made modern astronomy possible, for the certainty of its data enables us to measure not only the dimensions of the solar system, but also the approximate dimensions of the visible universe.

Not less important to the progress of science and to the general advance in human enlightenment are the achievements of the allied science of geology. It cannot boast, as yet, like geodesy, of a high degree of precision in measurement and calculation, for it deals, in general, with phenomena which have not

yet been reduced to simple laws. But, on the other hand, its subject-matter is more obvious and tangible, and it appeals therefore more forcibly and continuously to the average mind. No science seems comparable with geology in the completeness with which its history and its main processes are contained in the subjects and objects of investigation. Whoso would read the story of the earth's crust will find it written and illustrated in infinite detail in the rocks themselves. No vivid or perfervid imagination of the historian has concealed the facts or misinterpreted their sequence; they are all recorded with a truthfulness that shames the straightest human testimony and with a permanency which permits comparison and verification in endless repetition.

Geology illustrates more clearly, perhaps, than any other science the value of measurement and calculation when the order only of the quantity sought can be attained. The determination of the fact, for example, that nothing short of a million years is a suitable time unit for measuring the age of the earth, was an achievement whose importance can hardly be overestimated; indeed, our race may yet require decades, if not centuries, to appreciate its full significance, for in spite of the great advances in our times it appears probable that not one in a thousand of the good people with whom we live realizes how profoundly definite acceptance of such a fact must modify thought.

A criticism which the devotees of the so-called humanistic learning often apply to such matters of fact, and which is still occasionally accepted by men of science, helps us to see the absolute need of countless recurrences to the evidence so well exhibited in the crust of the earth. "Ah!" says the humanist, "I observe that the physicists and the geologists do not agree on the age of the earth. Some say it is ten million years, others that it cannot be more than two hundred million years, and others that it cannot be less than a thousand million years. I conclude, therefore, that so long as your doctors disagree in this manner, we may continue to accept the age recorded in our sacred books." Thus easy is it to mistake the order of a quantity for the quantity itself.

When we pass from terrestrial limitations to celestial phenomena the field for measurement and calculation is immensely enlarged, though the results attainable are less easy of ready appreciation. The Jovian, the Saturnian and the Martian subsystems, which have been pretty thoroughly explored by the observer and the computer, present to us the type, apparently, not only of the solar system, but of the galaxy of systems within telescopic view. And the surveys of the heavens now in progress indicate likewise that isolated stars are the exception rather than the rule, and that the visible stars are generally attended by one or more satellites, which are probably oftener dark than bright bodies. Visual and photographic measurements have, in fact, united in recent years in the demonstration that the number of material bodies in the universe is enormously greater than we have hitherto imagined. Here again, however, as in the case of the geological phenomena just referred to, we must be content to a great extent for the present with a knowledge of the order of the quantities measured and calculated. But to be able to state what is the order of the distances which separate the fixed stars from one another, the order of the volume of the visible universe, the order of the quantity of mass in that volume, and the order of the time unit requisite for the expression of the historical succession of celestial events, seems little short of a stupendous contribution to knowledge when one reflects on the obstacles, material and intellectual, that have stood in the way of its attainment.

The distances asunder of the stars are so great that the hundred and ninety odd millions of miles in the diameter of the earth's orbit about the sun make an inconveniently small base line for the measurement of the least of those distances and a hopelessly inadequate one for the measurement of the greatest of them. It would appear more fitting, in fact, to express such distances indirectly in the number of years it takes light moving at the rate of 300,000 kilometers per second to traverse them. Assuming with Lord Kelvin that the visible universe is comprised within a sphere whose radius is equal to the distance of a star whose parallax is one thousandth of a second, this dis-

tance would require light about three thousand years to pass over it, while the average distance asunder of the visible stars is considerably less, but still of the same order. Lord Kelvin has shown also in a profound mathematico-physical investigation recently published[1] how we may assign limits to the amount of mass in the visible universe. It appears from this investigation that there are something like a thousand million masses of the magnitude of our sun within that universe. The figures for this amount of mass have little meaning to most of us when expressed in ordinary units. The mass of the earth, for example, with its $6,000 \times 10^{18}$ metric tons,[2] is a mere trifle, for the sun has about 327,000 times as much mass as the earth. The mass of the sun therefore is the obviously convenient unit in this case; and we have only to imagine our solar system surrounded by a thousand million such suns, each in all probability attended by a group of planets, to get a sufficiently clear idea of the quantity of mass within visual range of our relatively insignificant terrestrial abode. And the time scale for the varied events which take place in the interaction of these millions of suns is not less imposing when expressed in familiar terms. A million years is the smallest unit suitable for estimating the history of a star, although the record of that history is transmitted to us through the interstellar medium by vibrations whose period is so brief as almost to escape detection.

Measurements and calculations have thus made known to us a range of phenomena which is limited only by our sense perceptions, sharpened and supplemented by the refinements of mathematical analysis. In space and mass relations these phenomena exhibit all gradations from the indefinitely small to the indefinitely large; and in time they point backward to no epoch which may be called a beginning and forward to no epoch which may be called an end. Dealing chiefly with those aspects of phenomena which possess permanence and continuity,

[1] "On Ether and Gravitational Matter through Infinite Space," *Philosophical Magazine*, August, 1901. "On the Clustering of Gravitational Matter in any Part of the Universe," *Nature*, Vol. 64, No. 1669.

[2] The metric ton of 1,000 kilograms, or 2,205 pounds, is about the same as our "long ton" of 2,240 pounds.

or at least a permanence and a continuity compared with which all human affairs appear ephemeral and fleeting, measurement and calculation tend to raise man above the level of his environment. They bid him look forward as well as backward, and they assure him that in a larger study of the universe lies boundless opportunity for his improvement.

But while that sort of knowledge which has been reduced to quantitative expression has done more, probably, than all else to disclose man's place in and his relations to the rest of the universe, it would appear that mankind makes relatively little use of this knowledge and that we are not yet ready, as a race, to replace the indefinite by the definite even wherein such substitution is clearly practicable. It is a curious and a puzzling, though perfectly obvious, fact that mankind as a whole lives less in the thought of the present than in the thought of the past, and that as a race we have far more respect for the myths of antiquity than we have for the certainties of exact science. Our ships, for example, are navigated with great success by aid of the sextant, the chronometer, and the nautical almanac; but what company would dare set Friday as the day for beginning the transatlantic voyage of a passenger steamer? From time immemorial tradition has dominated reason in the masses of men. Each age has lived, not in the full possession of the best thought available to it, but, rather, under the sway of the thought of some preceding age. We are assured even now, by some eminent minds, that the highest sources of light for us are nearly all found in the distant past; and a few go so far as to assert that modern science is merely furbishing up the half-lost learning of ages long gone by.

The work of academies and other scientific organizations is therefore nowhere near completion. Great strides toward intellectual emancipation have been made during recent times, but they have served only to enlarge the field for, and to increase the need of, that sort of knowledge which is permanent and verifiable. Measurement and calculation have furnished an invaluable fund of such knowledge during the two centuries just past, and we have every reason to anticipate that they will

furnish a still more valuable contribution to such knowledge in the centuries to come. R. S. WOODWARD.

## PUBLIC LECTURE.

On February 26, a public lecture was presented under the auspices of the Section of Biology, by Professor **Bashford Dean**, of Columbia University, entitled "Journeyings of a Naturalist through Japan and the Philippines."

Professor Dean referred to the zoölogical relations of the Japanese archipelago with the adjacent continent on the one hand, and with the island series on the other; *i. e.*, first, the Aleutian, second, through the Bonin Islands with the region of New Guinea, and third, through the Liu Chiu Islands with Formosa and the Philippines. The importance of the Line of Blakiston separating the Hokkaido from the southern islands was emphasized.

Special attention was called to the favorable facilities for zoölogical work which are offered in the region of Misaki, near the mouth of the Bay of Yokyo, and to the work of the Marine Laboratory of the Imperial University in this region. Dr. Dean had an opportunity of examining the centers of animal artificialization, an art in which the Japanese have been so eminently successful. Especially praiseworthy is the method of oyster-culture practiced in the Inland Sea near Hiroshima; hardly less interesting were the establishments in which varieties of gold fish are propagated, and even more striking were those for the cultivation of the breed of Tosa fowls, in favorable specimens of which the tail features attain the great length of fifteen feet. Success in the maintenance of this breed appears to be due to the selection of those fowls in which moulting occurs irregularly, and the effort is made to suppress entirely the moult in that region of the fowl where long feathers are to be produced. In referring to a journey in the Philippines, Professor Dean described many interesting experiences, particularly, those at Maujuyod, where living specimens of *Nautilus* were obtained. HENRY E. CRAMPTON,

*Secretary.*

## SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

February 28, 1902.

Section met at 8:30 P. M., R. S. Woodworth presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered:

**J. H. Bair,** Quantitative Relations between Motor and Sensory Associations.

**J. B. Miner,** Involuntary Muscular Responses to Rhythmic Stimuli.

**Clark Wissler,** The Ergograph: Comparative Results with Springs and Weights.

### Summary of Papers.

Mr. **J. H. Bair** reported on some quantitative studies in sensory and motor association. His experiments have been carried out by aid of a typewriter, the subject reacting to different stimuli by striking different keys. Curves were presented showing the rate of formation of association. If, after the stimuli have been presented many times in the same order, the order is then changed, the association is interferred with, and the more so the firmer it has become. If the typewriter keys are interchanged, so that the reaction to each stimulus must be changed, this interferes still more with the association. These results showed, then, that the association of definite sense impressions with definite motor reactions was more persistent than the association of sense impressions with other sense impressions following in serial order, or than the association of movements with other movements following in serial order.

In the discussion of this paper, several other facts were mentioned, showing the importance of motor reactions in the formation of association. Professor Thorndike had observed that good visualizers, who are able to picture mentally a page of printed matter that they have read, yet cannot read off the pictured words; apparently because the visual images are not associated with motor responses.

Mr. **J. B. Miner** spoke on "Involuntary Muscular Responses to Rhythmic Stimuli." He described some experiments conducted by himself at Columbia and Minnesota universities, in which tracings were obtained for non-voluntary hand and head movements when the subjects listened to a series of uniform sounds. It has been noted by Thaddeus L. Bolton and others in their investigation of rhythm that such a series of sounds appears not uniform, but as if coming in groups of two or more sounds. The muscle responses obtained correspond with this perception of rhythm, one wave coinciding with each rhythmic group. The movements recorded strikingly agree with another phenomenon of rhythm in that a motor wave shows for each stimulus when the sounds came slowly (forty per minute), but when the rapidity of the sounds was increased the wave encompassed two, three and even four sounds. This agrees with the introspective observation that the subjective group includes more units as the sounds come more rapidly. On the basis of the data of muscular responses Mr. Miner believes that an adequate physiological explanation of rhythm may be formulated, while organic rhythms alone would not furnish a completely correlated activity.

Dr. **Clark Wissler** reported some ergograph experiments showing that the contracting muscle presents a power series which is constant, whether the resistance is applied by a spring or by a weight. While this power series is weakened by fatigue, the resistance value of any point in the muscle series is the same for a weight or for a spring. In other words, there appears no difference between the fatigue produced by weights and springs when estimated in terms of the muscle series.

R. S. Woodworth,
*Secretary.*

## BUSINESS MEETING.

March 3, 1902.

Academy met at 8:25 P. M., Professor Hallock presiding.

The minutes of the last business meeting were read and approved.

The following candidates for resident membership, approved by the Council, were duly elected:

Frederic Peterson, M.D., 4 West 50th street.

Adolf Meyer, M.D., Pathological Institute.

George I. Finlay, Columbia University.

S. Alfred Mitchell, Ph.D., Columbia University.

Adjourned.

Henry E. Crampton,
*Recording Secretary.*

## SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

March 3, 1902.

Section met at 8:30 P. M., Professor Hallock presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered:

**C. C. Trowbridge,** The Physical Nature of Persistent Meteor Trains.

**S. A. Mitchell,** Observations on the Flash Spectrum at the Sumatra Eclipse.

### Summary of Papers.

Mr. **Trowbridge** gave a list of forty meteor trains which had remained visible to the naked eye for from two minutes to over one hour, all of them seen by reliable observers. Several tables were exhibited, giving the size, shape and color of recently observed meteor trains.

Mr. Trowbridge gave his views as to the most probable composition of meteor trains, and presented several hypotheses which might account for their long-continued luminosity. These are the following: (1) Incandescence of the particles of the train; (2) phosphorescence of the train; (3) electrical discharges; (4) Reflection of the light from the sun, moon, or stars, by the particles of the train; (5) electrons striking the meteoric dust or the air particles in or about the train, causing

a fluorescent glow similar to that in a Crookes tube. The source of the electrons may be either the highly-heated meteor — in which case the long-continued luminosity of the train must be accounted for by a retardation of the fluorescence possibly due to the low temperature — or the electrons may come from the sun — in which case the explanation would be similar to that lately given by Arrhenius for the light of the aurora. The author stated that this last hypothesis has not, to his knowledge, been previously advanced. The balance of evidence seemed to show that the luminosity of the persistent trains must be primarily caused by energy of an electrical nature. The subject is one of practical importance owing to its bearings on meteorology.

The paper by Dr. **Mitchell** gave the results of observations on the flash spectrum, made by him at Sawah Loanto, Sumatra, during the eclipse of May 18, 1901. Through the courtesy of the Astronomical Director of the Naval Observatory, Dr. Mitchell became a member of the expedition sent out by the government to observe this eclipse. The spectroscope employed was a Rowland objective plane grating of 15,000 lines, used in connection with a cœlostat. The weather experienced at Sawah Loanto was like that at almost every other astronomical station in Sumatra, cloudy during totality. Through the clouds, nevertheless, a spectrum of the flash at the third contact was obtained, which showed 374 bright lines between *F* and *H*. Investigations into the reasons for the differences in intensities in the flash and the Fraunhofer spectrum, showed that the intensities depended upon the heights to which the reversing layers of the different metallic elements around the sun, extend. It was found possible to arrange the elements in three groups according to their atomic weights.

Comparisons were made with Norman Lockyer's list of "enhanced" lines, or those stronger in the spark than in the arc, to confirm, if possible, Lockyer's idea that the "enhanced" lines play an important rôle in the chromosphere spectrum. Fifty-seven per cent. of the "enhanced" lines of titanium were found in the flash, but at the same time all of these lines cor-

respond without exception to strong lines in the sun. On the other hand, so many cases were found where a strong "enhanced" line was not marked in the sun by a strong Fraunhofer line, nor by any line in the flash spectrum, that Lockyer's opinion does not seem to be supported.

F. L. Tufts,
*Secretary.*

## SECTION OF BIOLOGY.

### March 10, 1902.

Section met at 8:20 P. M., Professor Bashford Dean presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered:

**Henry F. Osborn,** The Four Phyla of Titanotheres.

**Bashford Dean,** The Early Development of Sharks from a Comparative Standpoint.

**Maurice A. Bigelow,** The Cytological Phenomena of Maturation and First Cleavage in the Cirriped Egg.

**C. C. Trowbridge,** The Effect of the Wind on Bird Migration.

### Summary of Papers.

Professor **Osborn** presented some results recently obtained for the U. S. Geological Survey Monograph. The lower Oligocene Titanotheres prove to belong to four distinct phyla, to which the prior generic names *Titanotherium*, *Symborodon*, *Megacerops* and *Brontotherium* may be applied. The chief distinctions are found to be in the dolichocephalic or brachycephalic form of the skull, in the shape, length, position and mechanical relations of the horns, and in the number and form of the incisor and canine teeth. Each genus obviously had distinctive modes of fighting, locomotion and feeding. *Titanotherium* extends from the base to the summit of the Lower Oligocene. It is distinguished by its long narrow skull, short horns, powerful canines, vestigial incisors. *Megacerops*, on the contrary, is broad-skulled, short-horned, with obtuse canines, and with at least one upper incisor. *Symborodon* is distinguished by the

narrowing of the anterior portion of the premaxillaries, reduction of all the anterior teeth, and by elongate horns placed immediately over the eyes. In *Brontotherium*, the horns are by far the largest and most powerful, and acquire an extreme anterior position, absorbing the free portion of the nasals; all the upper cutting teeth persist; great buccal plates are evolved; and the skull measured along the base line is extremely brachycephalic. The four types were illustrated by models and diagrams.

Professor **Bashford Dean** considered briefly some points in the development of sharks, and attempted to reduce the type of the early development of the recent types to that of their holoblastic ancestor. This form probably occurred within the strict limits of the group Elasmobranchii — for the absence of clasping organs in the palæozoic genera of Acanthodians and Cladoselachids predicates external fertilization, and eggs many in number and of small size. In the line of this comparison, reference was made to the early development of the Japanese "pavement-toothed" shark, *Cestracion japonicus*, in which, as the author showed in a recent number of the "Annotationes Zoologicæ," surface furrows are present traversing the yolk, and are best interpretable as reminiscent of holoblastic cleavage. In the peculiar type of early development in *Chimæra*, total cleavage is suppressed until about the time of gastrulation, when cleavage furrows appear in the region of the lower pole and come to divide the egg into a number of distinct blastomeres, only one mass of which, however, become enclosed in the yolk-sac of the embryo. The remaining blastomeres, by a process of continued division, provide nutriment for the embryo, *via* gills and gut. Dr. Dean announced the presence in *Chimæra* of a true archenteric invagination, occurring early and at some distance from the margin of the blastoderm. It is small in size, and has a distinct cellular floor. Its (anterior) dorsal wall was compared to the dorsal lip of the archenteron of sharks, as described by Rückert and others. The ventral wall of the archenteron of modern types of sharks has thus lost its cellular character during the process by which the em-

bryo acquired a more perfect and specialized (cænogenetic) mode of obtaining nourishment from the yolk.

The paper by Dr. **Bigelow** dealt chiefly with protoplasmic movements and associated displacements of the yolk-materials in various cirripede eggs during maturation and first cleavage. The telolecithal distribution of the egg-substances, the formation and disappearance of a yolk-lobe, and precleavage movements associated with differential distribution of the entoblastic materials were described. Finally, a turning of the first cleavage spindle from a transverse to an oblique axis of the ellipsoidal egg was compared with similar more extensive movements in nematode eggs.

Mr. **C. C. Trowbridge** presented the results of systematic observations on the effect of the wind on the migration of hawks and many other birds along the Atlantic coast. The principal points of the paper were illustrated by means of diagrams giving the directions taken by the migrating birds under the influence of different winds. It was shown that a knowledge of meteorology was necessary in considering this subject, because the effective winds depend on storm centers travelling eastward. In one case, in the height of the southward migration, a storm center off the coast of Maine caused northerly winds throughout 800,000 square miles in the eastern portion of the United States and Canada, the velocity of the wind area averaging 20 miles per hour. A former paper on the subject was briefly reviewed, in which the author showed that flights of hawks and other land birds during the migrations were due to the crowding of the birds in a narrow coast-line path by the wind. The recent observations, now, warrant the conclusion that hawks and many other birds regularly depend on a favorable wind as a help in their migratory movements, and as a rule, migrate only when favorable winds occur. A brief account was given also of a retrograde movement of migrating swallows in the spring, evidently due to a return flight of the birds after they had been blown far out of their course by a strong wind from the west.

An election of sectional officers being held, Professor Bash-

ford Dean was elected Chairman, and Professor H. E. Crampton Secretary for the coming academy year.

HENRY E. CRAMPTON,
*Secretary.*

## SECTION OF GEOLOGY AND MINERALOGY.

MARCH 17, 1902.

Section met at 8:20 P. M., Dr. A. A. Julien presiding.

The minutes of the last meeting of Section were read and approved.

This being the annual meeting of the Section, the first business of the evening was the election of officers for the ensuing year. Professor R. E. Dodge nominated Prof. J. J. Stevenson for chairman and Dr. E. O. Hovey for secretary. On motion of George F. Kunz, W. H. J. Sieberg was directed by unanimous vote of the Section to cast one affirmative ballot for the nominees. He did so and they were declared elected.

The following program was then offered:

**George F. Kunz,** EXHIBITION OF SPECIMENS.

THE CENTENARY OF JOHN PLAYFAIR'S DEFENSE OF JAMES HUTTON'S THEORY OF THE FORMATION OF RIVER VALLEYS: MEMORIALS BY PROFESSORS STEVENSON, KEMP AND DODGE.

**Richard E. Dodge,** AN INTERESTING LANDSLIDE IN THE CHACO CAÑON, NEW MEXICO. Illustrated with lantern slides.

**Richard E. Dodge,** ARROYO FORMATION. Illustrated with lantern slides.

**Gilbert van Ingen,** THE AUSABLE CHASM, NEW YORK. Illustrated with lantern slides.

**George F. Kunz** gave an exhibition of specimens illustrating the finding of epidote, grossularite garnet and twinned crystals of quartz of the Japanese type, associated with chalcopyrite, malachite and other ores of copper in a contact vein in limestone in the Green Monster Mining Co.'s mine near Solzer, Prince of Wales' Island, Alaska.

## Memorials of Hutton and Playfair.

Prof. **Stevenson** after speaking of the conditions prevailing in in British geology prior to the publication of Hutton's memoir in 1785, gave briefly the characteristic features of Hutton's doctrines, and accounted for the ease with which his work could be misunderstood and misinterpreted. He described the conflict to which the memoir led, and emphasized the bitterness of those who opposed the doctrines on theological grounds. The preparation of Playfair's work was due as much to a desire to defend Hutton as to support his theory. Playfair appealed to those opponents whose knowledge of the theory had been derived chiefly from attacks made upon it. For them he showed that the theory was beautiful, symmetrical and in no sense inconsistent with the Scriptures. In dealing with the other class of opponents, led by Kirwan and DeLuc, he used vigorous language, exposing their ignorance and insincerity, and denouncing the virulence with which they had given a theological turn to the controversy. In defending Hutton's theory, Playfair brought his own great resources to bear, now correcting errors, now elaborating the doctrine, and in some places hardly anticipating some of the great works of later days.

The inviting style gained many readers for Playfair's book, among them Greenough and his associates, who founded the Geological Society of London, that theory might be replaced by observation. Hutton's theory obtained final triumph in 1830, when Lyell published his "Principles." Playfair's work hastened the birth of geology as now understood by a full quarter of a century, and finally divorced our science from cosmogeny.

Professor **Kemp's** memorial was more in the nature of a review of Hutton's personal history. He said in part: James Hutton was born in 1726, and, after his school and university course, entered a lawyer's office to prepare for the bar. He disliked the law, however, and gave up the study after a year. Being greatly interested in chemistry, he took up the study of medicine, attending lectures at Edinburgh and Paris and taking his degree at Leyden in 1749. The career of a physician

did not attract him much, after all his preparation, and in 1752 he went to Norfolk to learn agriculture. There his mind first turned definitely to mineralogy and geology. In 1754 he settled on his ancestral estates in Berwickshire, where he remained fourteen years, with occasional visits to Edinburgh and more distant parts of the kingdom. In 1768 he gave up country life and removed to Edinburgh to devote himself entirely to the study of geology and kindred sciences. His untiring industry enabled him to accomplish a marvelous amount of work in chemistry and finally to elaborate his essays in geology, revolutionizing that science and, with the elucidation given his work by Playfair's "Illustrations of the Huttonian Theory of the Earth," raising it to the high plane which it has occupied ever since. Modern geology dates from the publication in the spring of 1802 of John Playfair's explanation, elaboration and defense of Hutton's theories.

Professor **Dodge,** in his memorial of Playfair, said in brief:

To James Hutton we owe many fundamental truths now recognized in physiography, and to John Playfair we owe the elucidation of these ideas, and their amplification.

The doctrine that rivers are the cause of their valleys, and the proof thereof is perhaps the most important foundational idea that we owe to the combined labor of these two geological worthies. Playfair's clear exposition of the possible origin of river terraces, his acute description of the relation of lakes to rivers, his analysis of the varied forms of shore-lines, and his emphasis of the importance of initial shore-lines, all clearly exploited in his illustrations, deserve to take rank with the much quoted passage on rivers and their valleys, as being accepted geographical truths far in advance of their time.

## Summary of Papers.

**Richard E. Dodge,** An Interesting Landslide in the Chaco Cañon, New Mexico.

On a high mesa to the southeast of the Chaco Cañon, and about four miles below Putnam, New Mexico, is a series of stone monuments about five feet high and four feet in diameter.

These monuments stand on the edge of the rim rock of an old escarpment nearly 300 feet high. The rim rock of the escarpment is a coarse brown sandstone capped by about two feet of thin-bedded dark-brown sandstone containing shark's teeth. The face of the escarpment has recently slipped along a series of joints running approximately parallel to face of escarpment, and in a general direction of S. 30° E. The recesses between slipped blocks can be sounded to a depth of over fifty feet, and are wider at base than top as a rule.

In the slipping an ancient rock "hogan" 20 feet in diameter has slid 2.5 feet vertically and 8.3 horizontally without displacing the rock walls to any serious extent.

**Richard E. Dodge,** ARROYO FORMATION.

An arroyo is a steep-sided, narrow gulch cut in a previously filled gravel and adobe valley in the arid West.

The study of process of formation of arroyos, some of which have been under observation for several years, seems to show that the work has changed from aggradation to degradation because of some influence that has caused the focusing of the running water. Such a concentration of water is made possible by overfeeding of the land, which removes the help of roots in holding soil particles, combined with the habit of cattle to move in processions along trails that make natural channels for water.

The study of the rate of valley filling or erosion is difficult, because of the tendency of arroyos cut in adobe to maintain nearly vertical walls, and because a fallen block of adobe may be sealed over in the next flood, so that it looks in place. This problem is of especial importance, because the adobe deposits in some places contain relics of human occupation to a depth of many feet. The exact or even the approximate antiquity of the deposits cannot be definitely determined, because of the several ways in which the order of events in such a case may be interpreted.

**Gilbert van Ingen,** THE AUSABLE CHASM.

This paper was a description of the geological and physical features of this celebrated locality, which incorporated the results

of the author's own observations with those which had been arrived at and published by others.

Edmund O. Hovey,
*Secretary.*

## SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

March 24, 1902.

Section met at 8.30 P. M., Livingston Farrand presiding.

The minutes of the last meeting of Section were read and approved.

The name of one candidate for resident membership was read and referred to the Council according to the By-Laws.

The following program was then offered:

**Clark Wissler,** The Growth of Boys.

**W. S. Kahnweiler,** A Trip through French Indo-China to the Angkor Wat.

On motion of Professor Boas, the Section reëlected Livingston Farrand as Chairman and R. S. Woodworth as Secretary.

Dr. **Clark Wissler** reported on the growth of boys. The annual physical measurements of some three hundred school boys were correlated to discover tendencies and directions of growth. It appeared from the data that growth was rather uniform, as for example, when a boy's legs were growing rapidly, his arms were also growing at a corresponding rate. By correlating the stature with its increment for the following year it was seen that the sign of correlation changes when the pubertial maximum of growth is crossed. This means that boys who are growing rapidly at twelve, for example, continue to grow rapidly until fourteen or fifteen, when they slow down, while those growing slowly before this period now grow rapidly. Thus it appears that the point of pubertial maximum rate of growth, as determined by mass measurements, is really the point dividing the boys who mature early from those who mature late. The relation is yet more in evidence when the annual increments are correlated without regarding the absolute measurements. The results as a whole seem to show that

the rate of growth in any particular year is of no special significance except as an index of the relative maturity of the individuals concerned.

Mr. **W. S. Kahnweiler** reported on a trip that he made last summer through French Indo-China to the Angkor Wat. His paper was illustrated with lantern views of the trip, and of the architecture and sculpture of the ancient temple. The history of the temple was briefly outlined.

R. S. Woodworth,
*Secretary.*

## BUSINESS MEETING.

April 7, 1902.

The Academy met at 8.15 P. M., President Cattell presiding.

The minutes of the last business meeting were read and approved.

The President stated that the Academy was coöperating with the American Institute of Electrical Engineers, Columbia University, and other scientific societies, in tendering a reception to Lord and Lady Kelvin on the evening of April 21; and that the members of the Academy would receive due notice with regard to tickets, etc.

The Committee on Constitution reported the document filed herewith,[1] which was read by the Recording Secretary. It was stated that a special meeting of the Academy, to take action upon this Constitution, would be called for some evening of the week of April 21st.

The Academy then adjourned.

Henry E. Crampton,
*Recording Secretary.*

## SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

April 7, 1902.

Section met at 8:30 P. M., Charles Lane Poor presiding. The minutes of the last meeting of Section were read and approved.

[1] See Appendix.

The following program was then offered:
**Percival Lowell,** MODERN MARS.

SUMMARY OF PAPERS.

Map making began with Beer and Mädler in 1840. Since then many charts have been constructed of the planet. Some of them are so old as to have been more or less forgotten, some are so new as not yet to be known. Collection and comparison of such of these maps as have marked advances in the subject lead to some not uninteresting conclusions. Such are presented in the accompanying series.

The series consists of twelve maps:

1. Beer and Mädler. . . . . . . . . . . . . . . . . . . . . . 1840
2. Kaiser . . . . . . . . . . . . . . . . . . . . . . . . . . . . 1864
3. Dawes by Proctor. . . . . . . . . . . . . . . . . . . . 1867
4. Résumé by Flammarion. . . . . . . . . . . . . . 1876
5. Schiaparelli . . . . . . . . . . . . . . . . . . . . . . . 1877
6. Schiaparelli . . . . . . . . . . . . . . . . . . . . . . . 1879
7. Schiaparelli . . . . . . . . . . . . . . . . . . . . . . . 1882
8. Schiaparelli . . . . . . . . . . . . . . . . . . . . . . . 1884
9. Lowell . . . . . . . . . . . . . . . . . . . . . . . . . . . 1894
10. Lowell . . . . . . . . . . . . . . . . . . . . . . . . . . . 1897
11. Lowell . . . . . . . . . . . . . . . . . . . . . . . . . . . 1899
12. Lowell . . . . . . . . . . . . . . . . . . . . . . . . . . . 1901

These maps fall naturally into three groups, dividing the history of areography into as many stages.

I. Those from 1840–1877.
II. Those from 1877–1892.
III. Those from 1892–1902.

The maps of the first group are characterized by large patches of light and dark areas. Maps 1–4 show these patches, and by their agreement prove that the patches are permanent in place. For the maps are the work of different observers made at different epochs of time.

The maps of the second group are distinguished by a network of fine, straight lines covering the bright areas of the

disk, the "canals" of Mars. This was the work of Schiaparelli.

The maps of the third group are differentiated by a similar system of "canals" in the dark regions. This is the work since Schiaparelli. It has resulted in a complete change in the belief as to the character of these "seas"; the permanency of the lines showing that the background must be land not water.

Inspection of the series results in three directions:

That the whole series are in fundamental agreement. The basic features appear directly throughout the first period, and as a groundwork upon which subsequently discovered detail is imprinted in the second and third.

The second deduction from these data is that the almost inconceivable regularity in the "canals" was an evolution in perception forced upon Schiaparelli by the objects themselves; not a feature imputed by him to them. His first map in 1877 showed them as arms or inlets of the sea penetrating the continents to great distances, but not characterized by remarkable regularity of form. His second map in 1879, shows them narrower, straighter, and in every way more peculiar. His third map, in 1882, presents them as of geometric precision; as he himself remarks, as if laid down by rule and compass. His fourth map shows that they afterward kept such a character.

Had this precision been of his devising, they should not have gained in it as time went on and as his eye grew versed in decipherment. That they did so, implies that the recognition was forced upon him from without.

The third deduction is that the evolution in detail marks the series, and can be traced steadily on from the beginning to the end. The additions made in each period find themselves superposed upon the work of the period before. Similarly each map of any given period adds to its predecessor and is corroborated and extended by its successor. Thus a chain of evidence is made by them whose strength depends upon this very intertwining of results.

S. A. MITCHELL,
*Secretary.*

## SECTION OF BIOLOGY.

Section met at 8:15 P. M., Professor Bashford Dean presiding.

The minutes of the last meeting were read and approved.

The following program was offered:

**J. H. McGregor,** The Ancestry of the Ichthyosauria.

**A. G. Mayer,** Color Patterns in Lepidoptera.

**C. C. Trowbridge,** The Function of Interlocked Emarginate Primaries in Soaring Flight.

### Summary of Papers.

Dr. **McGregor** accepted Baur's view that the Ichthyosauria are derived from Permian Rhynchocephalia, but stated that in a study of the Belodontia he had found new evidence as to the nature of the intermediate forms. The latter group is of undoubted Rhynchocephalian origin, and may almost be considered as a subdivision including forms modified for aquatic life. A comparison of Belodonts and Ichthyosaurs shows that both have evolved in the same direction, though modification has proceeded further in the Ichthyosaurs, which were marine in habit. Almost all of the skeletal features of the two orders are reducible to a common type, and, although not directly ancestral, the Belodonts must be considered as standing very near the line of descent of the Ichthyosaurs; the two orders probably had as a common ancestor some aquatic Rhynchocephalian of the upper Permian or lower Trias. The Ichthyosauria are thus brought into relation with the Archosaurian branch of the Reptilia.

Dr. **Mayer** presented the results of his study of the color patterns of 1,173 species of lepidoptera: 453 *Papilio*, 30 Ornithoptera, 643 Hesperidæ, and 47 *Castina*. Counting sexual differences, 1,340 individual insects were examined; 542 *Papilio*, 59 Ornithoptera, 688 Hesperidæ, and 51 *Castina*. The number of rows of spots, bands, or combination markings upon the wings were counted, and as well the number of spots in each individual row, and the number of interspaces over which each

band extended; the results show that each row of spots or bands exhibits a decided tendency to be of uniform color throughout, that rows very rarely break at or near the middle of their extent, and that the end spots of a row are more variable than those spots near the center. "Frequency polygons" were obtained from the above-mentioned data, for the rows of markings, for the number of spots in each row, and for the extent of bands measured in interspaces. Eight such frequency polygons were determined for the spots and bands on the upper and lower surfaces of the wings in the group of Papilio Ornithoptera. Of the four representing the conditions in the fore-wing, three exhibit two well-marked maxima, the numbers being arranged in descending series on either side of each. These maxima are three and nine spots, or bands extending over three or nine interspaces. If, now, *Papilio* be divided into the three subgenera *Papilio* s. str., *Cosmodesmus*, and *Pharmacophagus*, and be still further separated into the African, Indo-Australian, Europ-Siberian, and American forms, it is found that the insects of the subgroups still display the tendency to have three or nine spots, or bands extending over three or nine interspaces. This is not a matter of correlation, for only 32 of the 453 species of *Papilio* display *both* three and nine spots upon their fore-wings. It is somewhat difficult to explain this condition upon the hypothesis of natural selection, owing to the fact that *Papilios* of widely separated regions show the same tendency to produce these two maxima in the same manner. The Hesperidæ and *Castina* show no such tendency, hence it is not universal for Lepidoptera. If it be due to natural selection acting upon *Papilios* and restricting them to this condition, such selection must be universally operative in the case of *Papilio*, but not in the other species. It is easier, therefore, to assume a race tendency in *Papilio* to produce either three or nine spots upon the fore-wing, or bands extending over three or nine interspaces. Other results, quantitatively expressed, were brought out by the author.

Mr. **Trowbridge** gave the result of observations on flying birds for the purpose of showing that the emarginate primaries

of hawks, eagles and certain other birds are interlocked in flight. The speaker referred to his original paper on the subject in which the theory was set forth, which was presented by the late Professor W. P. Trowbridge before the National Academy of Sciences and the New York Academy of Sciences. The paper created some discussion in *Science* at the time, participated in by Dr. Elliot Coues, Professor Newberry, Professor Trowbridge and others. Mr. Trowbridge showed by a number of diagrams and photographs that the primary feathers of a number of birds are emarginate near their ends, and that the webs of the feathers are so shaped that when they are overlapped, a curved and rigid aëroplane is formed at the end of the wing, which, he considered, is of considerable advantage in swift sailing flight. The emarginations of the primaries of hawks and eagles are particularly pronounced, and permit firm interlocking. A table of observations was given, showing that the interlocking of the primaries does take place, the data having been obtained at New Haven during the autumn flights of hawks along the Connecticut coast. It appears that in the case of one species of hawk examined, ten wings out of forty had all five primaries interlocked, and that the number of wings having 60 per cent. of the primaries interlocked was twenty-nine, or 72 per cent. of the total number, forty. It was concluded that emarginate primaries of hawks and other birds are interlocked in flight on the following grounds: (1) It has been found that the webs of such feathers of hawks that had just been killed usually show deep notches where they have rested against one another, which notches could only result from habitual interlocking of the primaries; and (2) in every case of over twenty-five hawks killed while flying and examined immediately after they fall *some* primaries were interlocked (several slightly wounded birds not included). In the case of nineteen perfect specimens on one species, 67.9 per cent. of all emarginate primaries (190) were found to be interlocked. While it is not possible at present to show when the emarginate primaries are interlocked in flight the indications are, however, that this occurs when the wing is partly flexed, as in the case of hawks sailing

rapidly through the woods and flying in a strong wind. The important functions of interlocking appear to be: (1) To make more rigid the outer portion of the wing, that part of the aëroplane formed by the primaries, and (2) to produce a curve of the wing which enables the bird to have a better control of its swift flight through the air than the unlocked condition would permit. The end of the bird's wing when the primaries are interlocked becomes shaped somewhat like the blade of a propeller screw. The interlocking also would keep the primaries extended without muscular exertion on the part of the bird.

Considerable discussion was aroused by Mr. Trowbridge's paper. Dr. **Jonathan Dwight, Jr.,** presented a series of arguments against the theory of the speaker, to the effect, in brief, that in the absence of a proper controlling musculature, any such interlocking as that described could be brought about only by accident; that habitual interlocking would bring about, furthermore, conspicuous wearing of the vane in the areas of contact, a phenomenon not observed in emarginate primaries; and that he concluded from his extensive studies upon feathers and feather structure, that habitual interlocking did not take place. Mr. **Frank Chapman,** with a series of fine lantern slides of birds in actual flight, demonstrated that in some soaring birds, at least, which possess emarginate primaries these feathers are certainly spread and not interlocked. Mr. Chapman agreed with Dr. Dwight that the facts tend to support Allen's theory of the origin of emargination, namely that aërial friction wears down the web; and that no such function is to be attributed to emarginate primaries such as that ascribed by Mr. Trowbridge. Prolonged discussion followed, participated in by Mr. Trowbridge, Dr. Dwight, Mr. Chapman, Professor Dean, Professor Crampton and others.

HENRY E. CRAMPTON,
*Secretary.*

## SPECIAL BUSINESS MEETING.

APRIL 24, 1902.

The Academy was called to order at 8:15 P. M., by President Cattell. Professor Richard E. Dodge was elected Recording Secretary, *pro tem.*

The President stated the object of the meeting, and that a notice had been sent by the Recording Secretary to all resident members and fellows entitled to vote, in accordance with the requirements of Section 5 of the amended charter.

The proposed constitution, filed herewith,[1] was then read by the Recording Secretary, *pro tem.*, and on motion of Professor R. S. Woodward, seconded by Professor Francis E. Lloyd was unanimously adopted.

The academy then adjourned.

RICHARD E. DODGE,
*Recording Secretary, pro tem.*

## SECTION OF GEOLOGY AND MINERALOGY.

APRIL 24, 1902.

Section met at 8:30 P. M., Professor J. J. Stevenson presiding. The minutes of the last meeting of Section were read and approved.

The following program was then offered :

**Lea McI. Luquer,** ON THE DETERMINATION OF THE RELATIVE REFRACTIVE INDICES OF MINERALS IN ROCK SECTIONS BY THE BECKE METHOD.

**Austin F. Rogers,** THE MINERALS OF THE JOPLIN, MO., LEAD AND ZINC DISTRICT.

### SUMMARY OF PAPERS.

**Lea McI. Luquer** stated that in most schemes for the optical determination of minerals in rock sections, the birefringence and resulting interference colors are made the basis of the scheme of classification. It is also desirable, however, to bring into consideration an approximate knowledge of the indices of refraction, and where the relative differences in the indices of two adjoining minerals is required, the method devised by Becke is found to be very convenient. This method depends upon the principle of the total reflection of light, and with proper adjustment of the microscope, which is to be focused sharply on the

[1] See Appendix.

dividing plane between the two minerals, it is possible, by slightly raising the objective, to observe a "bright line" on the side of the mineral having the higher index of refraction.

The main precautions to be observed are, that the cone of incident light be small, the sections very thin, the cementing material not much lower in refractive index than either of the minerals to be determined, and the plane of contact nearly vertical and clear. When the contact plane is much inclined, the method cannot be applied.

By this method very slight differences in refraction can be distinguished; as for example, between quartz sections cut parallel and at right angles to the optic axis; in which the difference

$$= 0.009, \quad = 1.553, \quad = 1.544.$$

Dr. **Luquer's** paper has been published in the *School of Mines Quarterly* for January, 1902, pp. 127–133.

**Austin F. Rogers** stated that the minerals of the Joplin District include sulphur, galena, sphalerite, covellite, greenockite, wurtzite, chalcopyrite, pyrite, marcasite, quartz, cuprite, pyrolusite, limonite, calcite, dolmite, smithsonite, cerussite, aurichalcite, hydrozincite, malachite, azurite, calamine, muscovite, chrysocolla, allophane, pyromorphite, barite, anglesite, leadhillite, caledonite, linarite, gypsum, goslarite, chalcanthite, melanterite, copiapite and bitumen, all of which have been found by the writer.

Lamellar twinning has been observed in galena, the twinning planes being vicinal tetragonal trisoctahedra. Covellite is found replacing sphalerite. Wurtzite occurs in distinct hemimorphic crystals — the first instance of the kind to be reported. Twin crystals of marcasite are common, among them cyclic fivelings. Quartz crystals are rare and small. Calcite presents an interesting field for crystallographic study, about twenty-four types, with a total of twenty-nine crystal forms, having been noted. Twinning according to all of the four laws for calcite have been observed. Some distinct crystals of aurichalcite confirm D'Archiardi's observations that the mineral is monoclinic

and that the axial angle is not 90°. Calamine occurs in doubly terminated crystals which show their hemimorphic character plainly. Seamon's theory as to the formation of calamine from "tallow-clay" is not in all cases applicable. The rare copper-lead basic sulphates, caledonite and linarite occur at one mine at Galena, Kansas. This mine also furnishes covellite, cuprite and aurichalcite.

The observed paragenesis generally follows this order: dolomite, galena, sphalerite, chalcopyrite, marcasite, pyrite, barite, calcite. The total absence of certain silicates and the rarity and small size of the quartz crystals strongly precludes the theory that the lead and zinc ores have been brought up from great depths by hot water.

Attention was called to the coincidence in the location of the ore deposits of this and neighboring districts and the border areas of the Ozark uplift, as pointed out by Haworth.[1]

A fuller discussion of the minerals noted in this paper and their occurrence will be found in the forthcoming Lead and Zinc Report of the University Geological Survey of Kansas.

Section adjourned at 9:40.

EDMUND O. HOVEY,
*Secretary.*

## SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

APRIL 28, 1902.

Section met at 8:25 P. M., Livingston Farrand presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered:

**Robert MacDougall,** TWO EXPERIMENTS IN COLOR VISION.

**J. E. Lough,** MEMORY OF SCHOOL CHILDREN.

**J. McKeen Cattell,** INTENSITY OF LIGHT AND THE ERROR OF PERCEPTION.

**E. L. Thorndike,** SEX DIFFERENCES WITH RESPECT TO VARIABILITY.

[1] Bull. Geol. Soc. Amer., 11: 231, 1900.

**W. Bogoras,** Ethnological Observations in Northeastern Siberia.

## Summary of Papers.

The paper by Professor **Robert MacDougall,** in his absence, was read by title. He found (1) that the subjective intensity and saturation of a given constant objective color increases with the retinal area illuminated by it. This increase is most marked in case of green, least marked in case of red. A similar phenomenon appears in the grays. The apparent difference in brightness between a patch of gray and a light or a dark background is increased by enlarging the patch. (2) A given area of illumination produces a stronger subjective effect when this area is divided and distributed over the retina than when it is compact. This is perhaps because the area of irradiation is increased by distributing the area of illumination.

Professor **J. E. Lough** reported some experiments on the memory of school children. He had tested 682 school girls, ranging in age from 9 to 15. The method employed was the same as that used by Lobsien in a similar investigation of the school children at Kiel. A list of ten words was read to the pupils, who then wrote down as much of the list as they could remember. This was repeated with new classes of words until eight lists had been given. These experiments show: (1) That memory improves but slightly between the ages 9 and 15, being 62 per cent. at 9 and 64 per cent. at 13 and 15. This is in sharp contrast with the results obtained by Lobsien — 38 per cent. at 9, and 75 per cent. at 13. (2) That the amount remembered depends upon the class of words composing the list — names of colors having an average of 87 per cent., names of concrete things 75 per cent., words connected with tactile experiences 70 per cent., emotions 68 per cent., sounds 58 per cent., abstract words 50 per cent., numbers 45 per cent. (3) That the usual retardation at 12 with accelerations at 13 is shown in each class of words, with the exception of emotions, where there is a marked retardation at 13, with acceleration at 14. (4) That in each of the lower grades of school (4A–5B) the

brighter pupils have the better memory, while in each of the higher grades (6A–7B) the duller pupils have the better memory.

In discussing this paper, it was remarked by Professor Thorndike that grammar school girls of 14 to 15 do not fairly represent all girls of that age, since the brighter individuals are apt to leave the grammar school before reaching 14 years.

Professor **Cattell,** in a paper on the "Intensity of Light and the Error of Perception," described experiments in which 211 shades of gray between white and black were sorted out into the order of brightness. The steps were smaller than can be perceived, and there was consequently an error of displacement, measuring the just observable difference. For the more accurate observers the error was six cards or about 0.03 of the range between white and black. Observers differ within the extremes of about 1 : 2. The just observable difference increases with the magnitude of the stimulus, but not in direct proportion as required by Weber's law. The increase is more nearly in proportion to the square root of the magnitude, which the speaker has found to hold in other cases and has elsewhere attempted to explain.

Professor **E. L. Thorndike** presented results bearing on the question of "Sex Differences with Respect to Variability." A large number of psychological tests of school children has afforded him the opportunity of comparing the variability of boys and girls, as classes, and, on the whole, there is practically no difference between them.

Dr. **W. Bogoras** reported some results of his recent observations, undertaken for the Jesup North Pacific Expedition, in northeastern Siberia, among the Chuckchi, Koryak and Kamchadal peoples. These he found to resemble each other strongly in the structure of their languages and in their folklore. What is especially interesting is the striking similarity, almost identity, between some of their traditions and some of those current among the North American Eskimos and the Indians of British Columbia. It is not, however, the Asiatics living nearest to Bering Strait, but more southerly tribes, that show most evidence of kinship with the Indians. R. S. Woodworth,

*Secretary.*

## BUSINESS MEETING.

May 5, 1902.

The Academy met at 8.15 P. M., President Cattell presiding.

The minutes of the last regular business meeting, and of the special business meeting of April 24, were read and approved.

The Secretary reported from the Council as follows: That arrangements had been made with the authorities of the American Museum of Natural History whereby the Academy would meet in rooms of the Museum during the coming year; that the Committee on the Constitution was considering necessary modifications of the by-laws, and would report at the meeting in October; and that the Committee on the Budget for 1902 had presented the report, filed herewith, which had been adopted by the Council.

The following candidate for membership, approved by the Council, was duly elected:

Miss Ida H. Ogilvie, New York City.

The Academy then adjourned.

Henry E. Crampton,
*Recording Secretary.*

## REPORT OF THE COMMITTEE ON THE BUDGET.

To the Council, New York Academy of Sciences:

*Gentlemen* — Your Committee, appointed for the purpose of formulating the Budget for the Academy "year," March 1 to December 31, 1902, presents the following estimates. The income for the above period is estimated at $3,000.00.

| | |
|---|---|
| Rent, Chemist's Club (March 1 to May 30) | $ 125.00 |
| Expenses, Recording Secretary | 300.00 |
| " Librarian | 300.00 |
| " Treasurer | 45.00 |
| Dues, Scientific Alliance | 40.00 |
| General Expenses | 100.00 |

| | |
|---|---|
| Editor.................................... | 1,000.00 |
| Total.......................... | $1,910.00 |
| Surplus.......................... | $1,090.00 |

Respectfully submitted,

J. McKeen Cattell,
Charles Lane Poor,
Henry E. Crampton.

## SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

May 5, 1902.

Section met at 8:30 P. M., Charles Lane Poor presiding. The minutes of the last meeting of Section were read and approved.

The following program was then offered:

**R. W. Wood,** Anomalous Dispersion and its Bearing on Astrophysical Problems.

**W. S. Day,** An Experiment Relating to the Application of Lagrange's Equations of Motion to Electric Currents.

### Summary of Papers.

Dr. **Day's** paper was as follows:

The experiment was analogous to one mentioned by Maxwell in his "Treatise on Electricity and Magnetism," Section 574, Volume II. Maxwell's experiment was made for the purpose of discovering whether or not, in the expression for the kinetic energy of an electric current, there was a term depending on the product of the current and the velocity of the conductor. In a single linear circuit having only one degree of mechanical freedom, the expression for the kinetic energy of the system in the most general case would be of the form:

$$T = \tfrac{1}{2} I\dot{x}^2 + K\dot{x}\dot{y} + \tfrac{1}{2} L\dot{y}^2$$

in which $\dot{x}$ is the velocity of the mechanical coördinate, $\dot{y}$ is the current, $I$ is a quantity of the nature of a mass, $L$ is the self-

induction of the circuit, and $K$ is the coefficient of the term consisting of products. Just what mechanical coördinate is to be represented by $\dot{x}$ is partly a matter of choice. Maxwell chose one whose velocity means a motion of the wire in the direction of its length. There is one other coördinate which seems to be geometrically possible, although it is not one that is naturally suggested by the most satisfactory hypotheses now in vogue as to the nature of an electric current. This other coördinate is one such that its velocity means a rotation of the wire carrying the current around its axis of figure. If $\dot{x}$ has this meaning, then if the coefficient $K$ is not zero, Lagrange's equations of motion show that if a current is suddenly started or stopped in a wire there would be an impulsive torque acting on the wire. The experiment was performed to look for such an effect, if it existed. A straight piece of aluminium wire 30 cm. long and 0.25 cm. in diameter was suspended by a quartz fiber in such a way that it was free to rotate, and by means of mercury cups, a current could be passed through it at pleasure. No effect of the kind considered was detected. If the value of $K$ expressed in C.G.S. electromagnetic units, and referred to a centimeter of the wire, had been as great as 0.00002, it could have been detected.

S. A. MITCHELL,
*Secretary.*

## SECTION OF BIOLOGY.

MAY 12, 1902.

Section met at 8:15 P. M., Professor Dean presiding. The minutes of the last meeting of Section were read and approved.

The following program was then offered:

**Edmund B. Wilson**, CELL-LINEAGE AND THE STUDY OF HOMOLOGIES.

**Gary N. Calkins**, ARTIFICIAL PARTHENOGENESIS IN PARAMŒCIUM.

**Francis B. Sumner**, FURTHER EXPERIMENTAL STUDIES UPON FISH DEVELOPMENT.

## Summary of Papers.

Professor **Wilson** pointed out that in the analysis of cell-homologies, as in genetic homologies in general, the essential criterion is that of common ancestral descent. Cell-homologies may be merely incidental or secondary to regional homologies of the egg, and, owing to the plasticity of cleavage-forms, may be more modified than other forms of homology, even becoming obliterated. It was proposed to denote as *equivalent* those cells giving rise to homologous structures, irrespective of their origin; while those cells which are alike in ontogenetic origin and position may, irrespective of their fate, be termed *homoblastic.* The term homology is applicable in cleavages of like pattern which have been derived from a common ancestral type, and in which the corresponding cells are both homoblastic and equivalent. When the cells, though homoblastic, wholly change their equivalence, or when the cleavage-pattern itself wholly changes, the original homology disappears.

Dr. **Calkins** presented the following results: The experiments in cultivating *Paramœcium caudatum* through long periods seem to indicate that, after continued feeding on the same diet, two originally different lines become so similar in chemical composition that conjugation is practically ineffectual. To illustrate, so-called "wild" conjugations were captured, and the ex-conjugants after separation were treated with the regular culture medium; 84 per cent. of these continued living. In the regular culture series (now, May 13, in the 567th and 523d generation, respectively), out of 48 exogamous ex-conjugants, only three continued to live, *i. e.*, about 6 per cent.; while of the 32 endogamous ex-conjugants only two continued to live, again about 6 per cent. The high percentage of fertile wild, and the low percentage of fertile cultivated forms give reason for the assumption that after continued treatment with the same diet, the conjugants get no new chemical compound by exchange of nuclei, and therefore no "rejuvenation" takes place. Experiments with different kinds of reagents are now in progress to ascertain, if possible, what is needed to make such sterile conjugations fertile.

Dr. **Sumner** described his further experiments upon the eggs of *Exocœtus, Salvelinus, Batrachus,* and two species of *Fundulus.* The methods employed were cautery and impalement with glass needles. The results tended to prove that there is early established in the embryo a definite region of growth, and that the elongation of the body occurs through cell-multiplication in this region. Additions from the germ-ring or other portions of the blastoderm play at most a subordinate rôle. Destruction of this region of growth led to cessation of embryo formation, although the blastoderm continued to spread. On the contrary, destruction at an early period of the entire embryonic sector of the blastoderm was followed by the regeneration of a new "embryonic shield."

Henry E. Crampton,
*Secretary.*

## SECTION OF GEOLOGY AND MINERALOGY.

May 19, 1902.

Section met at 8:15 P. M., Dr. A. A. Julien presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered :

**George E. Ashby,** Some Inclusions in Mica and their Relation to the Percussion Figure.

**George I. Finlay,** Geological Observations along the Northern Boundary of Montana.

### Summary of Papers.

Mr. **Ashby** was able to show by a most interesting series of specimens and lantern slides that definite geometrical relations exist between the percussion figures and the inclusions of magnetite common in mica. The percussion figure often bisects the same angle between the skeleton rays of magnetite.

Mr. **Finlay** dealt with the stratigraphy and petrography of the district along the 49th parallel of latitude west from the great plains. The sedimentary series is of Algonkian argillite,

sandstone and limestone. Intrusive and extrusive flows of dionite and biabase were observed and a few dikes of diabase were noted. The structure of the range at this point is simple, being that of a very gentle syncline, except for the anomalous contact along the eastern face of the Rocky Mountains between the Algonkian sediments above and the Cretaceous sandstones immediately below. This condition is brought about by overthrust faulting along a warped plane dipping very gently to the west.

GEORGE I. FINLAY,
*Secretary, pro tem.*

## BUSINESS MEETING.

OCTOBER 6, 1902.

The Academy met at 8:30 P. M., President Cattell presiding.

The minutes of the last business meeting were read and approved.

The Secretary reported from the Council that, in accordance with the provisions of the new Constitution, a new set of By-laws had been draughted by a special committee, and had been accepted by the Council. By direction of the Council, these By-laws were to be acted upon at the present meeting of the Academy. The Secretary then presented the new By-laws, which, by vote, were adopted. A copy is filed herewith.[1]

The following candidate for active membership, approved by the Council, was duly elected:

Alexander S. Farmer, C.E., 140 Rodney Street, Brooklyn.

The Academy then adjourned.

HENRY E. CRAMPTON,
*Recording Secretary.*

## SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

OCTOBER 6, 1902.

Section met at 8:45 P. M., Professor Hallock presiding.

The minutes of the last meeting of Section were read and approved.

[1] See Appendix.

The following program was then offered:

Informal Reports of the members upon work during the summer in matters of interest to the section.

### Summary of Papers.

**George F. Kunz** exhibited a section of the tusk of the elephant Tip that was killed several years ago because he had become so cross. The section of the tooth showed a large cavity amounting to a couple of cubic inches — near the end of the conical cavity at the root of the tooth. It was suggested that possibly this cavity represented an ulceration of the tooth, and that the bad humor of the elephant was really due to a bad tooth. After discussion by Professor Cattell and others, it was apparently the opinion of those best qualified to know, that this cavity was not the result of any such ulceration, and that probably the elephant would not suffer from toothache in any case.

**William Hallock** made an informal report upon barometric and boiling point observations made during the ascent of Mt. Whitney during the month of August. He called attention to the use of the boiling point apparatus as checking the barometer and the necessity of taking into consideration the temperature and humidity of the air, as well as the simple barometric pressure. He also referred to certain interesting lava fields on Whitney Creek to the southwest from Mt. Whitney.

**G. B. Pegram** gave an interesting account of the work done at the magnetic observatories in this country, and especially at the one at Cheltenham, Md., with which he was connected during the summer vacation.

Dr. **D. S. Martin** referred to the interesting minerals exhibited at the Exposition of the South at Charleston, and showed a sample of the ash from Mt. Pelée which was brought to Charleston on one of the incoming vessels. He will report upon this subject in the section of mineralogy later on.

D. S. Martin,
*Secretary, pro tem.*

## SECTION OF BIOLOGY.

October 13, 1902.

The section met at 8:15 P. M., Professor Bashford Dean presiding.

The minutes of the last meeting were read and approved.

The Secretary presented a letter from the Recording Secretary of the Academy, calling attention to the fact that sectional officers were to be elected at the November meeting, the officers then chosen to take office at the first meeting in January following. It was also stated that the election of a Chairman by the section constituted his nomination to the Council as a candidate for Vice-President.

The following nominating committee was appointed by the Chair to report at the next meeting: Professors Bristol, Lee, Lloyd, Drs. Mayer and Calkins.

The scientific program consisted of a series of reports by members of the section upon their work during the summer.

Professor **E. B. Wilson** spoke of some of the results of his successful work, carried on at first at the Beaufort, N. C. Fish Commission Station, and later at the South Harpswell Laboratory in Maine. Complete embryological material of *Renilla* had been obtained, after several years' efforts. Important results were also obtained by experiments upon the regeneration of the large claw in *Alpheus*, the conclusions of Przibram being confirmed, and the influence of the nervous system being determined. At South Harpswell experimental work was carried on upon the development of the normal eggs, of isolated blastomeres, and of egg-fragments of the worm *Cerebratulus*, a form extremely favorable for experimentation. In conclusion, the favorable character of the fauna in general in this region was pointed out.

Professor **F. S. Lee** reported the results of investigations upon the effect of alcohol on muscular work in *Gonionema*, which agreed in essentials with his earlier work upon the effect of alcohol on frog muscle. It was pointed out that the effect

might be due to the withdrawal of water from the muscle, or to the action of the small number of ions present.

Dr. **O. P. Hay** described his summer's work upon the fossil fishes of the American Museum of Natural History, particular attention having been given to the Cretaceous forms. Work was also carried on upon the turtles.

Professor **A. W. Grabau** spoke of his collecting expeditions for Silurian and Devonian fossils. He mentioned also an interesting case of non-conformity at Rondout, which he had been able to explain. Explorations of the Palæozoic coral reefs of Wisconsin were also described.

Dr. **G. N. Calkins** referred to the investigations which had been carried on at the Marine Biological Laboratory, under his direction, upon the sporozoa associated with cancerous growth. It was found that the genus *Basiophra* when introduced into the body of a toad would cause the production of a tumor. Dr. Calkins's personal work upon *Paramœcium* had been continued, the action of various salts upon this form receiving particular attention.

Dr. **M. A. Bigelow** reported upon his observations upon the power of young birds to distinguish different colors, of interest in connection with the problem of insect coloration. Much of the summer had been utilized in the preparation of a manuscript for a laboratory manual.

Mr. **Naohide Yatsu** described the results of his experiments upon the eggs of the common starfish, which were carried on at Woods Hole. Artificial parthenogenesis was induced by ether, and larvæ were reared up to the eighteenth day.

Mr. **Raymond Osburn** described the location and work of the Vancouver Island Laboratory of the University of Minnesota, where he had spent the summer. His particular interest concerned the invertebrata and birds of the Vancouver region.

Professor **Crampton** referred to the work of the Woods Hole Laboratory, and mentioned briefly his work at the Bayshore Laboratory upon the development of *Bulla* and of his experiments upon moths.

Professor **Dean** reported progress upon several lines of research. A paper dealing with Japanese oyster-culture had been prepared for the government, and experiments upon induced fossilization by means of calcium phosphate had been pursued. The embryology of *Chimæra* had received special attention, a conclusion of particular interest being that the breaking up of the extra-embryonic yolk is due to supernumerary sperm-nuclei.

HENRY E. CRAMPTON,
*Secretary.*

## SECTION OF GEOLOGY AND MINERALOGY.

OCTOBER 20, 1902.

Section met at 8:15 P. M., Prof. J. J. Stevenson presiding.

The minutes of the last meeting of Section was read and approved.

The following program was then offered:

**William H. Hobbs,** GEOLOGY OF THE RIVER CHANNELS ABOUT MANHATTAN ISLAND.

**James F. Kemp,** COMMENTS ON THE GEOLOGY OF BINGHAM CAÑON, UTAH. Illustrated with lantern slides and specimens.

**Wallace G. Levison,** EXHIBITION OF SPECIMENS OF GNEISS AND SERPENTINE FROM THE SOUTHERN END OF MANHATTAN ISLAND.

Before the scientific program of the evening was taken up, the Section proceeded to the election of officers for the year 1903, in accordance with the provisions of the new constitution of the Academy.

James F. Kemp was nominated for chairman, and, there being no other nominations, the Section, by unanimous vote, directed the Secretary to cast one affirmative ballot for the nominee, and Professor Kemp was declared elected.

Edmund O. Hovey was nominated for Secretary, and, there being no other nominations, the Section, by unanimous vote, directed Professor R. E. Dodge to cast one affirmative ballot for the nominee, and Dr. Hovey was declared elected.

## Summary of Papers.

**Wallace Goold Levison** exhibited to the Section four specimens of gneiss obtained from the bedrock in certain deep excavations at the southern end of Manhattan Island. One of these was collected July 20, 1902, from a depth of fifty feet below the surface at the corner of Broad and Exchange Streets; the second was collected in the excavations at 40 Exchange Place, forty-five feet below the surface, on July 25; two others were collected at 43–49 Exchange Place, forty-five feet below the surface, on July 25. Mr. Levison also showed several specimens of serpentine from boulders found in excavations for the Stock Exchange building on Broad Street, between forty and sixty feet below the surface, on June 19.

In the absence of the author, the paper by Professor **William H. Hobbs** was read in somewhat condensed form by the Secretary of the Section. The paper was accompanied by a wealth of detailed observations too extensive for reproduction, but a summary of his conclusions is as follows:

In his introduction the author called attention to the unusual opportunities now offered for studying the geology of Manhattan Island through the numerous great engineering works in progress. The waterways surrounding the island are deep cañons, with a depth of nearly two hundred feet in the East River and three hundred feet or more in the North River, now partly filled with drift deposits, the amount depending upon the velocity of the tidal currents.

In 1865 Stevens advanced the theory that the river channels followed lines of faults ("longitudinal and transverse fractures"). Newberry regarded the East River as the lowest reach of the Housatonic River before it discharged its waters into the Hudson, which was then the outlet of the Lorentian series of lakes, and he considered the Harlem River with Spuyten Duyvil Creek a smaller tributary of the Hudson. Dana believed that the relatively easy solution of certain beds of limestone determined the position of the river channels. This view of Dana's has been supported by Kemp and F. J. H. Merrill, while Gratacap rejects the theory advanced by Stevens.

Professor Hobbs finds that no correspondence can be established between the directions of the belts of limestone or dolomite and of the New York water front, except within the stretch from Kingsbridge to Macomb's dam bridge. Along this line too the observed facts point to the occurrence of a narrow strip of limestone dropped down between vertical faults. The sections of the Harlem River which are furnished by the bridges across it show clearly that it is not a simple erosion valley resulting from cutting by the stream. The bed of the stream is marked by sudden changes of level, and the Harlem seems to have chosen its course quite independently of ridges of the harder gneiss. Under the East River limestone has been found at but two localities — under the channel east of Blackwell's Island, and in one of the drill holes underneath the Manhattan pier of the East River bridge No. 3. The limestone east of Blackwell's Island is enclosed between parallel fault walls, and appear to have been dropped down along them. The numerous occurrences, however, of gneiss, and gneiss only along, in and under the East River leave little doubt that the main portion of the bed is composed of this rock.

Regarding the bedrock beneath the North River, comparatively little is known, but the origin of its channel is sufficiently accounted for by its position along the contact of the Newark system with the crystallines. This contact seems surely to be a fault border, on account of its markedly rectilinear extension, the great scarp of basalt, the much inferior position of the newer terranes, and the evidence derived from the borings along the route of the proposed tunnel of the Pennsylvania, New York and Long Island Railroad Company.

The author holds that the directions of the channels of Spuyten Duyvil Creek and Harlem and East Rivers have been determined largely by lines of joining and displacement. Manhattan Island borders directly upon the Newark area, in which the existence of a network of faults has been established by the work of several observers, and the network probably extends beyond the limits of the area. The striking rectilinear outlines of the island, especially of the northern half of it, and its topo-

graphic development are favorable to the view that it represents an orographic block left standing between down-thrown strips of the crust. The rectilinear gorge of the upper Harlem between Washington Heights and Fordham Heights is continued, so far as its western wall is concerned, some two and a half miles south of the river. It is parallel to the direction of the scarp of the Palisades and of the Hudson. Besides the cross fractures indicated by the different parts of the Harlem River which were pointed out by Stevens, several other cross fractures on and about Manhattan Island were pointed out by the same author. Dana also considered that the Manhattanville cross valley was formed by a cross-fracture. A considerable number of faults has been definitely established. Their directions correspond in general to the elements in the courses of the river channels. The exceptions to this rule are the fissures in the East River east and west of Blackwell's Island.

The author went on to cite a number of faults which have been disclosed by numerous borings and tunnels, and in closing called attention to the fact that the buried rock surface in the lower part of the city (south of Twenty-third street), as well as that below the area of the Harlem flats (north of One Hundred and Tenth Street and east of Eighth Avenue) is characterized by the most abrupt changes of level. In his opinion the area of these portions of the island represent orographic blocks depressed by faults, reefs of gneiss and limestone rising along the Harlem area, while reefs of gneiss alone characterize the southern district.

Professor **Hobbs'** paper was discussed briefly by Professors Kemp, Dodge and Stevenson, and it was evident that the author's theory would not be accepted without considerable further investigation.

At the outset of his paper on Bingham Cañon, Professor **Kemp** stated that the article was not a formal one for publication, and that he did not wish to forestall in any degree the forthcoming Bingham folio by Mr. Boutwell of the United States Geological Survey. He then described the geological formations in the vicinity of the large mines. These formations em-

braced the great section of quartzite with smaller exposures of limestone and with intruded masses of eruptive rocks which range from pronounced porphyries to granites. At least three kinds of eruptives can be distinguished. The author described in outline the faults and geological relations of the ores, and stated that the ores especially favored the contact of the eruptive rocks with the quartzites. The evidences of contact metamorphism between the porphyries and the limestones were commented upon. The ores in the great porphyry dike on the claims of Colonel Wall were described, and were stated to be secondary in their origin — that is, they probably were introduced in solution into a mass of crushed eruptive rock. The data for the paper were gathered in connection with the field instruction given to a class of students the past summer. The paper was illustrated by means of lantern slides, maps and specimens.

EDMUND O. HOVEY,
*Secretary.*

## SECTION OF ANTHROPOLOY AND PSYCHOLOGY.

OCTOBER 27, 1902.

Section met at 8.15 P. M.

At the preliminary business meeting Professor Edward L. Thorndike, of Teachers College, Columbia University, was elected as Chairman of the Section for 1903.

The program of the evening consisted of anthropological reports of summer work. Dr. **Clark Wissler** described his researches among the Sioux Indians in the interests of the American Museum of Natural History, paying particular attention to their decorative art as compared with that of surrounding tribes. Dr. **A. L. Kroeber,** of the University of California, spoke of the field work carried on by that institution under his direction, dwelling particularly upon the distribution of linguistic stocks in California and the correspondence between linguistic and cultured areas.

Dr. **Maurice Fischberg,** of New York, outlined a study in which he is engaged involving the measurements of, and collec-

tion of information regarding the Jews of New York. Immigrants are examined particularly with regard to racial peculiarities and observations on several generations in the same families are made wherever possible. Dr. Fischberg discussed briefly certain preliminary results from his research, promising fuller reports at a later date.

Dr. **Farrand** closed the program with a few remarks on his work during the summer on the Sahaptin stock of Indians for the American Museum of Natural History.

LIVINGSTON FARRAND,
*Secretary, pro tem.*

## BUSINESS MEETING.

NOVEMBER 3, 1902.

The Academy met at 8.20 P. M., Professor Charles L. Poor presiding. The minutes of the last business meeting were read and approved.

There being no business to come before the Academy, it was voted to adjourn.

HENRY E. CRAMPTON,
*Recording Secretary.*

## SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

NOVEMBER 3, 1902.

Section met at 8:30 P. M., Charles Lane Poor presiding. The minutes of the last meeting of Section were dispensed with.

The following program was then offered :

**G. B. Pegram**, EXPERIMENTS ON THE ELECTROLYSIS OF RADIOACTIVE SUBSTANCES.

### SUMMARY OF PAPER.

When a solution of a thorium salt is electrolyzed, using platinum electrodes, a temporary radioactivity is imparted to the anode rather than to the kathode, which is remarkable in view

of the fact that in the air near dry thorium compounds a negatively charged body, corresponding to the kathode, becomes radioactive, while a positively charged body, corresponding to the anode, is not made active. The activity of the anode used in the electrolysis of a thorium nitrate solution can become much more intense, for a given extent of surface, than that shown by a thick layer of thorium oxide.

The solution under electrolysis rapidly loses its power of imparting radioactivity, so that after four hours of electrolysis with a current of half an ampere, a solution of 20 g. of thorium nitrate in 100 c.c. water had lost 95 per cent. of its power of imparting activity to the anode. This radioactivity of the anode increases for a while after being taken out of the solution, then its intensity falls off at the rate of half its value in eleven hours, which has been shown by Professor **E. Rutherford** to be the rate of decay in the case of surfaces made active by exposure to the emanation from a dry thorium compound. The radiation is not homogeneous, as is shown by a study of its absorption by successive layers of metal foil.

The activity of the anode seems to increase directly with the concentration of the solution for short periods of electrolysis, but its relation to the current strength and the duration of the electrolysis appears to be less simple.

Solutions containing radium impart activity to both anode and kathode, but this activity decays very rapidly, falling off half its value in about 35 minutes.

S. A. Mitchell,
*Secretary of Section.*

## SECTION OF BIOLOGY.

November 10, 1902.

The Section met at 8:15, P. M., Professor Bashford Dean presiding.

The minutes of the last meeting were read and approved.

The Nominating Committee appointed at the October meeting presented the following nominations :

For Chairman and candidate for Vice-President, Professor Bashford Dean.

For Secretary, Dr. M. A. Bigelow.

The Secretary was authorized by vote to cast a single affirmative ballot for these nominees. This was done, and the candidates declared duly elected.

The scientific program consisted of a lecture by Professor **R. T. Jackson**, of Harvard University, entitled "Localized Stages in the Development of Plants and Animals."

### Summary of Paper.

Professor **Jackson** showed that in the study of organisms marked stages in development are found throughout life from the young to adult and old age. Such stages are of the highest importance in phylogenetic studies as affording the key to genetic relations.

In addition to stages in the direct development, in many plants and animals stages exist in localized parts throughout the life of the individual, which are directly comparable to stages found in the young, and to the adults of simpler and more primitive fossil or living types.

Localized stages are typically seen in organisms that grow by progressive addition of similiar parts, in which the young or growing part temporarily or permanently presents characters which are closely comparable to characters found in the young and adults of simpler types.

In plants localized stages are seen in the distal and proximal areas of the leaf, in suckers, "witches' brooms," late, sickly or otherwise feeble growths, and, as shown by Cushman (*American Naturalist*, November, 1902) in spring growths and leaves below the flower. The last mentioned are particularly striking as they present a localized senescence, repeating stages in inverse order of sequence from that seen in the seedlings.

In animals localized stages are seen in the newly-added dorsal inter-ambulacral plates of the corona of *Strongylocentrotus* and other sea-urchins. In young plates of the stem of some crinoids, (*Platycrinus*, *Pentacrinus*) and as pointed out by Grabau, in the

distal ends of the arms of *Eucrinus* and *Platycrinus*. The septal suture of *Ammonites* show striking localized stages, in that a progressive complexity of the septum is traceable in passing from the dorsal to the ventral border which series is comparable to the progressive complexity seen in passing from the young to adult, and from primitive to specialized types in the geological series.

HENRY E. CRAMPTON,
*Secretary*.

## SECTION OF GEOLOGY AND MINERALOGY.

NOVEMBER 17, 1902.

Section met at 8:15 P. M., J. J. Stevenson presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered:

**A. W. Grabau,** LIMESTONE REGIONS OF MICHIGAN.

SUMMARY OF PAPER.

The limestones considered are of middle Devonian age, and constitute the bedrock of the northern portion of the lower peninsula of Michigan. They are of great economic importance on account of their purity. They are chiefly used in the manufacture of Portland cement, and for chemical purposes. Throughout them isolated reefs are found, which show all the characters of modern coral reefs. The corals and coralines are in the place they grew, while on all sides of them the fragmental limestone derived from the erosion of the reefs is found. This constitutes most of the bedded limestone of the region. On the flanks of the reef it has a steep dip, while away from it, the dip becomes low. The bedded limestone shows all the character of sandstones, but runs as high as 96 or even 99 per cent of $CaCO_3$.

The fossils in the limestones show a mingling of Corniferous and Hamilton types, in the lower beds. A migration from this region to the Ontario and New York region is indicated.

Illustrated with diagrams and specimens.

J. F. KEMP,
*Secretary, pro tem.*

## SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

November 24, 1902.

Section met at 8:15 P. M., Professor Farrand presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered:

**J. B. Miner,** Time Intervals Bounded by Varied Stimuli.

**J. H. Bair,** The General Practice Curve.

**R. T. MacDougall,** On the Relation of Reactions to Certain Secondary Stimuli.

### Summary of Papers.

Mr. **J. B. Miner** presented the results of some experiments on the perception of time intervals bounded by varied stimuli. Intervals of one, two, three, four and six seconds bounded by sounds, lights, or one sound and one light, were given the subject, who then endeavored to reproduce the interval by taps on a telegraph key. For intervals bounded by sounds, the reproduced interval changed from plus to minus at a point between intervals of two and three seconds. There is very little difference between intervals bounded by sounds and those bounded by lights; but a considerable difference is given when the interval is bounded by a sound followed by a light or *vice versa.* The same interval bounded by varied stimuli seemed to the subjects to be longer than where bounded by like stimuli. Memory of intervals bounded by varied stimuli required more effort. Mr. Miner believed that this represented the difference in difficulty of muscular adjustment on which the memory of the time interval depended. The increase in variability with the longer intervals followed the law suggested by Cattell and Fullerton, rather than Weber's law.

The paper by Mr. **Bair,** on the general practice curve, was read in his absence by Mr. Miner. This paper was based on experiments made with a pack of 48 cards (six different pictures and eight of each picture). The cards when dealt in the same

order and then immediately after in a different order required a longer time for the second order. If dealt 2, 3, 4, 5 $\cdots n$ times in the same order before dealing in some new order, the successive practices in the same order followed the law of the practice curve, which is an asymptotic approach to a physiological limit; and at the same time dealing the cards in any order required also less and less time. This shows that practice in one order gives practice ability in another order antagonistic to it, and the more practice in one order the greater the ability to respond quickly to the new order.

Professor **MacDougal** reported upon a series of experiments showing the influence of variations in visual stimulation upon reactions to auditory signals. Reaction time was shorter in darkness than in light, in weak light than in strong light, and in colored than in neutral light. Reaction time was more constant under neutral than under colored light, and changes in quality of light were followed regularly by increased rapidity of reactions. These changes were apparently due to changes in the attentive condition of the reactor, not to any immediate organic influence of the intensity or quality of the light.

James E. Lough,
*Secretary.*

## BUSINESS MEETING.

December 1, 1902.

The Academy met at 8:20 P. M., President Cattell presiding. The minutes of the last business meeting were read and approved.

The Secretary reported from the Council as follows: that the Council had voted to nominate the following as candidates for Fellows, to be voted upon at the Annual Meeting: E. F. Buchner, Esther F. Byrnes, R. H. Cunningham, A. W. Chester, William Dutcher, H. C. Dyar, G. I. Finlay, John Eyerman, W. J. Gies, A. W. Grabau, J. D. Irving, Gustav Langmann, H. R. Linville, J. E. Lough, R. T. MacDougall, T. C. Martin, Adolf Meyer, S. A. Mitchell, H. C. Parker, F. Peter-

son, J. C. Pfister, J. D. Prince, H. G. Piffard, M. I. Pupin, Ivan Sickels, M. A. Starr, G. T. Stevens, C. A. Strong, F. B. Sumner, W. G. Thompson, C. C. Trowbridge, J. F. Woodhull, E. R. VonNardroff: that the Council had prepared a list of nominations for officers (which was read), which would be mailed to members or the Academy one week before the Annual Meeting.

The Secretary read a letter from the Secretary of the Scientific Alliance, relating to the establishment of The Herrman Fund for scientific research. A copy of the letter is appended.

The Academy then adjourned.

Henry E. Crampton,
*Recording Secretary.*

## SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

December 1, 1902.

Section met at 8:30 P. M., Charles Lane Poor presiding. The minutes of the last meeting of Section were read and approved.

The following program was then offered:

**G. W. Ritchey**, Recent Results in Astronomical Photography with the Forty-inch Refractor and with the Two-foot Reflector of the Yerkes Observatory.

### Summary of Paper.

Mr. **Ritchey** exhibited with the lantern some excellent photographs taken by him with the instruments of the Yerkes Observatory. The two-foot mirror of silver on glass was ground some time ago by Mr. Ritchey himself, and the mounting of it was made in the observatory workshop from his designs. Since the reflector was mounted two or three years ago, many exceptionally fine photographs have been taken of star groups, clusters and nebulæ, which rival those superb photographs of Keeler. Especially interesting were the photographs of *Nova Persei*, which showed the changes in the nebulosity which surrounds this interesting new star.

Another important piece of work taken up by Mr. Ritchey was the application of a color screen to celestial photography, thereby adapting a visual telescope to photographic work. Such a screen was used with the great forty-inch refractor of the Yerkes Observatory, and photographs were exhibited showing the excellence of Mr. Ritchey's work with this giant object glass.

S. A. MITCHELL,
*Secretary.*

## SECTION OF BIOLOGY.

DECEMBER 8, 1902.

The Section met at 8:15 P. M., Professor F. E. Lloyd presiding.

The minutes of the last meeting were read and approved.

The Secretary presented a letter from the Recording Secretary, regarding the establishment by the Scientific Alliance of the Herrman Research Fund, stating also the method of presenting and forwarding applications for grants.

The following program was then offered:

**Edmund B. Wilson,** ON THE RELATION BETWEEN LOCALIZATION AND CLEAVAGE AS ELUCIDATED BY EXPERIMENTS UPON MEROGENY.

**A. W. Grabau,** THE PHYLOGENY OF THE FUSIDÆ.

SUMMARY OF PAPERS.

Professor **Wilson** presented the results of his experiments upon the eggs of *Cerebratulus*, which dealt with the problem of germinal localization. It was found that isolated blastomeres of the two-cell stage developed by partial cleavage, but that dwarf larva of a normal structure were finally produced. The upper part of a blastula, however, produced a larva which lacked a perfect archenteron; and a ventral portion of a blastula became a pilidium which was devoid of an apical organ. The development of egg-fragments obtained prior to the initial cleavage, furnished particularly illuminating results. An egg-fragment obtained before maturation, and fertilized later devel-

oped by total cleavage into a perfect larva of dwarf size. It thus appears that localization is progressive, being practically absent before the initial cleavage, appearing in the two-cell stage, and becoming greater in the different regions of the blastula. The relation between cell-division and differentiation was discussed. It is expected that this paper will be published in full at an early date.

Professor **Grabau** showed that the Fusidæ are among the more highly accelerated types of marine gasteropods of the modern fauna. *Fusus* itself dates back to the Eocene, occurring in the Paris and Hampshire basins. The American Eocene species generally referred to *Fusus* are shown by their protoconchs to be more nearly related to *Pleurotoma* although their adult form is like that of the typical *Fusus*. The protoconch of *Fusus* is highly accelerated, showing riblets on the last portion. The typical conch ornamentation appears abruptly. The earliest stage is characterized by round whorls, rounded ribs extending from suture to suture, and simple spirals. These are the characters of the adult of the most primitive Eocene species, and also appear in the young of all later species. The next stage is characterized by the appearance of an angulation on the whorl, and a concentration of the ribs on the angle. In the next stage the ribs are replaced by tubercles, and these later unite to form a keel. This gives the type of the genus *Fusus colus*. In the old members of this species the keel is lost, and the whorls become rounded. Finally in highly accelerated types the adult is marked by the rounded keelless whorl, while many of the intermediate stages are dropped out. Thus *F. longicauda* has dropped the tubercled and keeled stage through a process of acceleration in development. This may be considered as phylogerontism. In every genetic series of the Fusidæ types occur, which in their adult conditions, show characters comparable to one or the other of the stages found in such types as *F. colus*. In the chronogenesis of each series it is found that types whose adults are comparable with the earliest stage of *F. colus* appear first. All Eocene species of *Fusus* for example are of the simplest type. The more complicated

types, whose adults correspond to later stages in the ontogenesis of *F. colus*, appear progressively later and later in time, while at the same time primitive species persist to some extent. A number of distinct lines of divergence or radiation have been found within the genus *Fusus*, each paralleling the *F. colus* series, so that for each member of this latter series a corresponding member can be usually found in each of the other series. Similar series have been worked out among the Eocene Clavilithoids, and a number of other Eocene and later groups. The ontogeny of hundreds of individuals has been worked out with reference to the shell structure, and these data have served as the basis for the determination of the phylogeny of the principal series among the Fusidæ.

Henry E. Crampton,
*Secretary.*

## ANNUAL MEETING.

December 15, 1902.

The Academy met for the annual meeting at 8:15 P. M., President Cattell in the chair.

The reports of the officers for the past year were called for and presented as follows :

The Recording Secretary stated for the Corresponding Secretary, that no correspondence had been carried on.

The report of the Recording Secretary, filed herewith, was read.

The report of the Treasurer, filed herewith, was received too late for presentation.

The accompanying reports of the Librarian and Editor were read.

No nominations for honorary members or corresponding members were presented.

The following list of candidates for Fellows, nominated by the Council according to the By-Laws, was read ; the Secretary was empowered to cast an affirmative ballot of the Academy therefor, which was done :

Edward F. Buchner,
Esther F. Byrnes,
R. H. Cunningham,
Albert W. Chester,
William Dutcher,
Harrison G. Dyar,
John Eyerman,
George I. Finlay,
Wm. J. Gies,
Amadeus W. Grabau,
John D. Irving,
Gustav Langmann,
H. R. Linville,
J. E. Lough,
R. T. MacDougall,
T. Cumerford Martin,
Adolph Meyer,
S. A. Mitchell,
Herschel C. Parker,
Frederick Peterson,
J. C. Pfister,
H. C. Piffard,
John D. Prince,
Michael I. Pupin,
Ivan Sickels,
M. Allen Starr,
George T. Stevens,
C. A. Strong,
F. B. Sumner,
W. Gilman Thompson,
C. C. Trowbridge,
E. R. VonNardroff.
John F. Woodhull,

The election of officers for the coming year was then held. Tellers were appointed, ballots were distributed, the votes received and counted. The following officers were elected :

President, J. McKeen Cattell.

Vice-Presidents : Section of Geology and Mineralogy : James F. Kemp. Section of Biology : Bashford Dean. Section of Anthropology and Psychology : E. L. Thorndike. Section of Astronomy, Physics and Chemistry, C. L. Poor.

Corresponding Secretary, R. E. Dodge.

Recording Secretary, Henry E. Crampton.

Treasurer, C. F. Cox.

Librarian, Livingston Farrand.

Editor, C. L. Poor.

Councillors : (Three years), Franz Boas, H. C. Bumpus ; (two years), D. W. Hering, N. L. Britton ; (one year), E. B. Wilson, G. F. Kunz.

Finance Committee : John H. Caswell, John H. Hinton, C. A. Post.

Vice-President Kemp then took the chair, and President Cattell presented his annual address, entitled "The Academy of Sciences."

At the close of the address, a vote of thanks was moved by Professor Wilson, seconded by Professor Osborn, and carried.

The Academy then adjourned. HENRY E. CRAMPTON,
*Recording Secretary.*

## REPORT OF THE RECORDING SECRETARY.

The present report deals with the work of the Academy from February 24, 1902, to December 31, 1902.

During this period twenty-three meetings of Sections of the Academy were held, at which four public lectures and forty-two stated papers were presented. The subjects were distributed as follows:

| | | |
|---|---|---|
| Section of Astronomy, Physics and Chemistry — | | |
| Astronomy, | 2 papers, 2 lectures. | |
| Physics, | 3 papers. | |
| | | 5 papers, 2 lectures. |
| Section of Biology — | | |
| Palæontology, | 2 papers. | |
| Zoölogy, | 10 papers, 2 lectures. | |
| | | 12 papers, 2 lectures. |
| Section of Geology and Mineralogy — | | |
| Geology, | 5 papers. | |
| Mineralogy, | 4 papers. | |
| Physiography, | 2 papers. | |
| | | 11 papers. |
| Section of Anthropology and Psychology — | | |
| Anthropology, | 3 papers. | |
| Psychology, | 11 papers. | |
| | | 14 papers. |
| Total, | | 42 papers, 4 lectures. |

At present there are 300 Active Members, and of these 96 are Fellows, while the election of 33 Fellows is pending. During the period under consideration four members (J. Woodbridge Davis, Dr. Benjamin Lord, Rev. E. A. Hoffman, D.D., LL.D.,

and Walter Shriver) have died. Five members have resigned, and one has been dropped; the total loss for the year is therefore ten. Eleven new members have been elected, one of them a life member, and three have been reinstated. There is therefore a net gain of four.

An important change has been made in the method of publication. Hereafter each article will be published as a separate brochure, to be distributed to those members who shall signify a desire to receive the publications. Together with the proceedings of the Academy, all articles will be published in collected form, when sufficient to make a volume of about 600 pages. By this procedure prompt publication is assured.

The past year has witnessed two events of primary importance to the Academy. In the first place, an entire formal reorganization has been effected. At the time of the last Annual Meeting (Feb. 24) a new charter had just been granted to the Academy by Act of Legislature; and by this instrument, which replaced that of 1817, greater freedom for activity and general expansion had been accorded the Academy. Pursuant to its requirements, a Committee of the Council was constituted for the purpose of drawing up a new Constitution and new By-laws; these have been prepared, accepted by the Council, and adopted by the Academy in business session. While the changes which have been made are more in the letter than in spirit, certain advantageous modifications have been introduced in matters of organization, terminology, and procedure. Among these may be mentioned the change of title of Resident Members to Active Members, the abolition of the restriction to the number of Fellows, the representation of the Sections in the Council by making their Chairmen, Vice-Presidents of the Academy, the constitution of the Editor as an officer, and the introduction of stated limitations to the terms of office of the President, Vice-Presidents and Councillors. In the By-laws, changes have been made in the mode of electing Active Members, now nominated directly to the Council, in the establishment of a class of Non-resident Members, and in the chapter relating to sectional organization.

The second event of importance is the change in the place of meeting. After several years of a somewhat roving existence, the Academy has found shelter with the American Museum of Natural History, where it is hoped it may remain for some time. The acknowledgments of the Academy are due to the Director and other officers of the Museum, for the courtesy and interest which have made this step possible.

HENRY E. CRAMPTON,
*Recording Secretary.*

## REPORT OF THE TREASURER.

### RECEIPTS.

| | | |
|---|---|---|
| Balance as per last Annual Report. . | | $1.878.07 |
| Annual Dues for 1896. . . . . . . . . . . . | $ 10.00 | |
| " " 1897. . . . . . . . . . . . | 10.00 | |
| " " 1898. . . . . . . . . . . . | 10.00 | |
| " " 1899. . . . . . . . . . . . | 30.00 | |
| " " 1900. . . . . . . . . . . . | 50.00 | |
| " " 1901. . . . . . . . . . . . | 110.00 | |
| " " 1902. . . . . . . . . . . . | 1,965.00 | |
| " " 1903. . . . . . . . . . . . | 30.00 | 2,215.00 |
| Initiation Fees . . . . . . . . . . . . . . . . . . | | 35.00 |
| Life Membership Fee. . . . . . . . . . . . . | | 100.00 |
| Interest to June 30 on St. Ann's Avenue Mortgage of $12,000. . . . | | 292.00 |
| Sales of Publications. . . . . . . . . . . . | | 11.62 |
| | | $4,632.19 |

### DISBURSEMENTS.

| | | |
|---|---|---|
| Expenses of Recording Secretary. . . | $ 200.25 | |
| " " " Librarian . . . | 166.65 | |
| " " " Treasurer. . . | 28.97 | |
| General Expenses . . . . . . . . . . . . . . . | 82.50 | |
| Printing Annals. . . . . . . . . . . . . . . . | 322.61 | |
| Lecture. . . . . . . . . . . . . . . . . . . . . . . . . | 25.00 | |
| Dues to Scientific Alliance. . . . . . . . | 50.12 | 876.10 |
| Balance on Hand. . . . . . | | $3,756.00 |

## Balance Sheet.

December 15, 1902.

| Dr. | | |
|---|---|---|
| Invested in Bond and Mortgage.... | $12,000.00 | |
| Cash on Hand.. ................ | 3,756.09 | |
| | $15,756.09 | |
| **Cr.** | | |
| Permanent Fund................. | | $10,686.43 |
| Publication Fund................. | | 1,823.69 |
| Audubon Fund.................. | | 1,897.25 |
| Income, Permanent Fund......... | | 219.37 |
| " Publication Fund......... | | 36.56 |
| " Audubon Fund.......... | | 36.57 |
| General Income Account......... | | 1,056.22 |
| | $15,756.09 | $15,756.09 |

Charles F. Cox,
*Treasurer.*

## REPORT OF THE LIBRARIAN.

The work of the Librarian during the past year has been concentrated upon the proper cataloguing and preservation of exchanges. This task has been chiefly in the hands of the Librarian's assistant, Mr. W. M. Erb, by whose energy the work has been kept practically up to date. As much attention as possible has also been given to the proper arrangement and care of the volumes already in the possession of the library. Efforts are being made to fill out the gaps in serial publications of value with very gratifying results.

The total number of exchanges on the Academy's list at present is 410; of these 313 are foreign and 97 from the United States and Canada.

The total number of volumes, parts of volumes and pamphlets received during the year is 2,400.

The total number on the mailing list of the Academy is 720, of which 292 are members, 410 exchanges and 8 subscribers.

The great need of the library at present is, as for some years past, an appropriation for binding, serious but unavoidable injury and loss constantly resulting from the insufficient protection afforded by the present arrangements.

Respectfully submitted,

LIVINGSTON FARRAND,
*Librarian.*

## REPORT OF THE EDITOR.

During the last year, owing to lack of funds, no scientific papers were published by the Academy. In March, the Academy issued Part 2, Volume 14 of the Annals, containing the Record of the Meetings of the New York Academy of Sciences, January, 1901, to December, 1901, by Richard E. Dodge, Recording Secretary. This was issued as a separate (No. 5, Volume 14, pages 85 to 163) and was mailed to every member of the Academy.

There is now a good balance in the hands of the Treasurer, to the credit of the publication fund, and publication of scientific papers may be resumed.

CHARLES LANE POOR,
*Editor.*

# PRESIDENT'S ADDRESS.

## THE ACADEMY OF SCIENCES.

Twenty-three centuries ago, when the first and fairest flowers of civilization were in blossom, Plato and his friends met together in an Athenian garden to talk of the things that appeared to them to be beautiful, good and true. The garden was called "The Academy," and the word has ever since maintained the high traditions of its origin, uniting the ideas of friendly social intercourse and the search for truth. The philosophy of Plato was passed on to his disciples, so that we read of fourth and fifth academies; it was transplanted to Rome, where Cicero named his country house "The Academy," and to Alexandria, where mystical neo-platonism long resisted the dogmatic rationalism of the church.

As part of the Italian renaissance, when civilization was once more young, vigorous and beautiful, as in the Greek period, the word "academy" was revived and used to name a society of scholars. Cosimo dei Medici, the Elder, established at Florence in the fifteenth century a *Platonic Academy*, and academies of letters by the hundred flourished in Italy during the sixteenth century. In 1560 there was established at Naples by the versatile Giambattista della Porta the first academy of sciences — *Academia Secretorum Naturæ* — to which only those were admitted who had contributed to the advancement of science or medicine. The academy at Naples was suppressed on the accusation that it practised the black arts; but soon afterwards there was established at Rome, with Galileo as one of its members, the *Accademia dei Lincei*, which was later revived and is now one of the great national academies.

The mere word "academy" is of course unimportant; societies of scholars are not always called academies, nor are all academies societies of scholars. The beginnings of associations for the advancement of knowledge are to be found in savage tribes, de-

veloping with the state of civilization, usually in the form of guilds of priests, until we reach the Greek period, whence we date our philosophy and our science. The culture of Greece was carried to Alexandria, where Ptolemy Soter, supposed to be the son of Alexander the Great, established the beginning of the *μουσεῖον*, based on the four corner-stones of science and culture, the university, the academy, the library and the museum; and this institution maintained its prestige for centuries. We have here an association of scholars that surpasses anything to be found in Greece or Rome, and one indeed that approaches an ideal more nearly that any existing institution. Supported by the government, we find men of science living together and working together, a system of lectures, a library of 600,000 titles and the like. To these conditions we may attribute the work of Aristarchus, Eratosthenes, Hipparchus, Ptolemy, Archimedes, Euclid, Herophilus and others, who in many ways established the principles of science. Similar if less important centers of learning arose in Bagdad, Damascus and elsewhere; and there was a series of Arabian astronomers, physicians and mathematicians who never permitted the torch of learning to become extinct until it was merged in the dawning light of modern science.

The records of Roman history are chiefly of wars and politics; but its institutions still dominate the world. The names of Pliny, Galen and Lucretius prove that science was cultivated. It is said that there were twenty-eight public libraries in Rome in the fourth century; and the schools of the Roman Empire never became extinct. Rome was the center whence first empire and then the church spread civilization throughout Europe. The removal of the seat of empire to Byzantium, the ever-recurring invasions of the barbarians from the north and the tenets of the Christian church are supposed to have extinguished learning and culture; and the period from the decline of the Roman empire to the revival of learning in Italy is called the dark ages. But perhaps these centuries are only dark in so far as they are obscured from our sight. It may seem absurd for an amateur in history to make an assertion contrary to the com-

mon views; but the scientific man, saturated with the doctrine of evolution, is loth to accept a spontaneous generation of culture at the period of the late Italian renaissance. Students of medieval history are indeed beginning to date back this period of awakening to the thirteenth or even to the eleventh century; but there appears to be much evidence for a gradual extension of civilization and culture throughout Europe from the sixth to the eleventh centuries.

It is a long way from the love passages of the Phædrus to those of the Vita Nuova, from the fawn of Praxiteles to the madonna of Giotto, from the Phrygian mysteries to the order of St. Francis. The Christian church is said to have been inimical to culture and science, but to it we owe the establishment of monasteries, schools and libraries throughout Europe. It is natural that the civilizations of Athens and of Rome should have become merged in the surrounding peoples. We might as well wonder why Shakespeare did not give rise to a line of poets, as to wonder why the Athens of Pericles was not permanent. When Rome came in contact with the peoples of the north, an average resulted which was in the end an extension of civilization. The barbarians who overran Italy and sacked Rome were themselves converted to Christianity, and the traditions of culture were carried beyond the Rhine and the English Channel.

Boetius, whose birth coincided with the fall of the western empire, wrote on science as well as on philosophy. From his death, in 525, education and learning were in the hands of the church. Gregory the Great, pope from 590 to 604, encouraged primary education; and monasteries, being at once schools, libraries and academies of learned men, were established everywhere under the early popes. Bede, born about 673, wrote on astronomy and medicine. At his school at Jarrow in Northumbria there were 600 monks in attendance besides strangers from a distance. Alcuin, born about the year that Bede died, went from the directorship of the school at York to establish the palace school for Charles the Great, making the court of the emperor more nearly an academy of sciences and letters

than has happened elsewhere in history. Alfred the Great in the following century also cultivated letters at his court, and himself wrote on scientific as well as on literary subjects. He established schools throughout his dominion, including an academy at Oxford.

The traditions attributing the University of Paris to Charles and Oxford University to Alfred are discredited; but the schools they supported and established certainly did not become extinct, but developed into the medieval universities. The curriculum of the monastic and cathedral schools may appear narrow and trivial—the well-known seven arts, the elementary trivium—grammar, rhetoric and dialectic, and the more advanced quadrivium — music, arithmetic, geometry and astronomy; but if we compare it with the curriculum of the American or English college of a few years ago we should cast no stones. Indeed, when we try to picture the state of affairs, the invasions of the Northmen and Saracens, the wars and pillages, we can but admire the spirit that maintained schools and libraries in the monasteries, the academies of sciences and arts of the time. The Roman Church, the Holy Roman Empire, civic life and independence and finally the universities were the offspring of the so-called dark ages.

The medical school of Salerno, whose beginnings are traced to the ninth century, seems to have descended directly from the Greco-Roman period. It was secular in character, extending its privileges to Jews and women. It is of interest to scientific men that the first university should have been a school of medicine, but it must be admitted that it did not contribute considerably to the advancement of science — at Alexandria the living human body was dissected, at Salerno Latin hexameters were written on the urine — nor has its imperfectly known organization the interest for us that attaches to the universities of Bologna and Paris.

The medieval university is certainly one of the most notable institutions known to history. It appears almost incredible that 10,000 students from all parts of Europe should have frequented Bologna, when traveling was as expensive, difficult and dan-

gerous as was the case in the thirteenth century. The guilds or trades unions of the students and teachers represent a kind of organization that is of peculiar interest to those of us who are concerned with the conduct of modern scientific societies. The present period is marked by combinations of labor and of capital, such as have not previously existed, but the guilds of the middle ages had a more complete organization, and the universities of scholars have no modern counterpart. It seems to me that we men of science suffer both in position and in character from the dependence to which we submit, and that we could with advantage learn from the *studium generale* of the middle ages.

The centers at Bologna and Paris developed almost simultaneously. Bologna was primarily a law school and Paris a theological school. The former was more strictly professional, and its students were mostly men of maturity, already holding positions in the church or state. The universities of students, representing different nationalities, obtained control and imposed their authority on the masters and on the city. The school at Paris was less professional in the sense that theology and philosophy were the liberal studies of the age. There was at Paris from the time of Abelard a vast number of teachers gathered together from all quarters; and the formation of a university of masters was followed in the thirteenth century by the complex organization of nations and faculties.

Migrations from Bologna established universities throughout Italy, while the influence of Paris led to the universities of Oxford and Cambridge, of Prague and of the various French cities. Science in the modern sense of the word did not play an important part in the medieval university; but Roger Bacon, born in 1214, was intimately associated with Oxford and Paris, and doubtless found encouragement as well as persecution at these universities. The promise of Bacon was not fulfilled for more than two centuries; but there was a slow growth of science at the universities. Copernicus found masters at Cracow, Bologna and Padua and was himself professor at Rome. Kepler and Galileo filled chairs at universities; they bring us to the period of the organization of academies of sciences.

Francis Bacon in his *New Atlantis*, published in 1627, pictures Solomon's House as an ideal academy of sciences. I have already referred to the establishment of actual academies of sciences in Italy during the sixteenth century. They were originally clubs of scientific men or men interested in science who met together to discuss and perform experiments. Like the early universities the academies were at first independent of the state; but they subsequently received charters and appropriations of money. In the sixteenth and the first part of the seventeenth century academies of sciences were founded throughout Europe. The period was marked by extraordinary scientific progress which was greatly stimulated by the interchange of ideas made possible by the academies. The state of science was such that each member could understand and take interest in the work of all the others. Intellectual curiosity was widespread, catholic and naïve.

The Royal Society of London and the Academy of Sciences of Paris arose at about the same time and under similar circumstances. At Paris a club counting among its members Descartes, Gassendi and Pascal met at a private house for some thirty years, until an academy of sciences was finally organized by Colbert on the model of the Académie Française established earlier under the auspices of Richelieu. The seven original members included Huyghens, who was called to Paris. They received pensions from the king and grants for instruments. The academy was reconstituted in 1699 with fifteen active members, three each in geometry, astronomy, mechanics, anatomy and chemistry. The academy of sciences became part of the Institute of France in 1795; at which time it was divided into ten sections in each of which were six members and six associates in the provinces, the sections being: (1) mathematics, (2) mechanics, (3) astronomy, (4) experimental physics, (5) chemistry, (6) natural history and mineralogy, (7) botany (8) anatomy, (9) medicine and surgery, and (10) agriculture. An eleventh section — geography and navigation — was added in 1803 with three members. As constituted since 1833, the Institute of France contains five academies: (1) Française, (2) In-

scriptions et belles-lettres, (3) Sciences, (4) Beaux-arts and (5) Sciences morales et politiques. The academy of sciences contains eighty members and the other academies forty. Each receives a pension. As we all know, the intellectual life of France has been centered largely at Paris and in the academies.

The Royal Society of London resulted from a club that held meetings as early as 1645 ; it was finally organized in 1660 and chartered in 1662. The membership was larger and less exclusive than in the case of the Paris Academy, and there has not been a division into sections. Under the existing statutes fifteen fellows are elected annually, and the membership numbers about 450. The fellows do not receive pensions as in the continental academies, but pay dues. The society, however, administers a government fund for research (£4,000 annually), and has in many ways coöperated with the government. There has been this year established a British Academy for the Promotion of Historical, Philosophical and Philological Studies.

The Accademia del Cimento, begun in Florence in 1657, and the Collegium Curiosum begun in Altorff, Franconia, in 1672, are types of the scientific clubs of the time. Somewhat later academies were established in various centers — the Berlin Academy in accordance with the plan of Leibnitz in 1700 and the St. Petersburg Academy by Peter the Great in 1724. The members receive salaries from the government ; at St. Petersburg these are liberal, so that at one time eminent foreigners, such as Nicholas and Daniel Bernoulli, were attracted to St. Petersburg by membership. Similar academies were established in the capitals and other cities of the continent — at Stockholm, Copenhagen, Munich, Madrid and elsewhere. These imperial and royal academies were patronized by kings and princes and were part of the court life of the time.

The American Philosophical Society, modeled by Franklin on the Royal Society, had its beginnings at Philadelphia in 1743 ; and the American Academy of Arts and Sciences, modeled by Adams on the Paris Academy, was established at Boston in 1780. Both institutions were originally of national scope and still maintain this character to a certain extent. Academies

more local in character were subsequently established in different cities, the Connecticut Academy of Arts and Sciences, founded at New Haven in 1799, being the oldest of these. Our own academy of sciences was organized in 1817 as the Lyceum of Natural History in the City of New York. The National Academy of Sciences was incorporated by Congress in 1863. It was born into a world that has changed, and we may hope progressed, since the golden age of academies. The differentiation of the sciences, the dispersal of our men of science over a wide area and the general trend of democratic institutions are not favorable to the academy of the type that flourished in the seventeenth and eighteenth centuries.

The nineteenth century witnessed an extraordinary development of scientific activity throughout the world. Each science has had its great leaders who have established new fundamental principles and new lines of investigation, while the workers in the ranks are now a great army. I have had occasion during the past year to compile a biographical catalogue of the living men of science of the United States. On my preliminary list there are eight thousand who have published scientific papers, with a few exceptions, admitted because they are engaged in teaching or other scientific work of some importance. I estimate that the scientific men of the world number about 50,000, not counting those physicians, engineers and others who do not directly contribute to the advancement of science, nor those who are engaged in historical, philological and other studies, not commonly included in the natural and exact sciences.

Under these circumstances scientific organization has been compelled to adjust itself to new conditions. The two great developments have been the establishment of large national associations holding migratory meetings and of special societies for the several sciences. The German Congress of Scientific Men and Physicians was established in 1828 and the British Association for the Advancement of Science in 1831. There are similar associations in other European countries, in Australasia and in South America. Our own association was estab-

lished in 1848, being a continuation of the Association of American Geologists and Naturalists, founded in 1840.

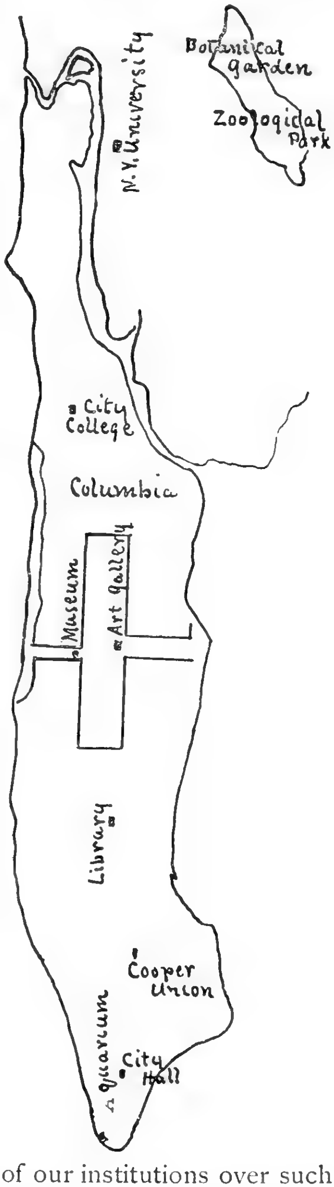
The Linnean Society for zoölogy and botany was founded in London in 1788 and received a royal charter in 1802. The Geological Society of London was established in 1807, and the Royal Astronomical Society in 1820. These societies were offshoots from the Royal Society, and were a necessary result of the differentiation of science and the increase in the number of men of science. At the time, however, they were supposed to weaken the Royal Society, its president, Sir Joseph Banks, saying, "All these new-fangled associations will finally dismantle the Royal Society, and not leave the old lady a rag to cover her."

The scattering of scientific men in this country delayed the establishment of special societies. The American Association was divided into two sections in 1875 and into nine sections in 1882. The American Chemical Society was established in 1876, and we now have national societies for the principal sciences—mathematics, physics, chemistry, astronomy, geology, botany, morphology, ornithology, anatomy, physiology, bacteriology, pathology, psychology and anthropology.

New York city and members of our academy have done their share in establishing and supporting these societies. The Torrey Botanical Club, begun in 1870, was the first of the special societies. The Chemical Society was established in this city and has its headquarters here. The American Mathematical Society began as the New York Mathematical Society and still has its main center in New York, as has also the American Physical Society. The secretaries of the American Physiological Society and of the American Psychological Association are officers of our academy, and the secretary of the American Geological Society was formerly one of our most active members. The societies for civil, mining, mechanical and electrical engineering have their headquarters in New York city.

Apart from scientific societies this city has, during the past fifteen years, witnessed an unusual, perhaps unparalleled, development of its scientific and educational institutions. Columbia University has become one of the dozen great universities of

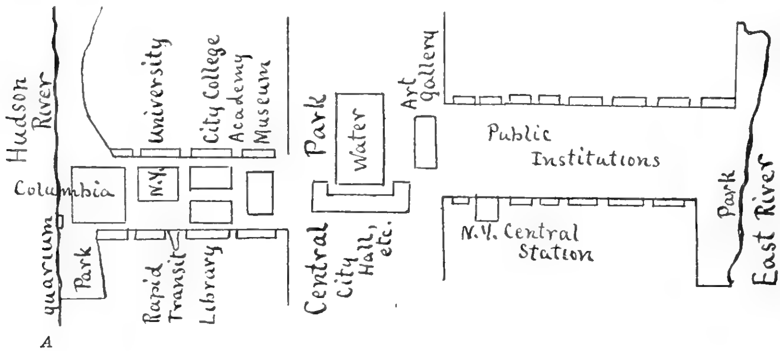
the world. Its new grounds and buildings, costing $8,000,000, are but a symbol of its educational position. New York University, with its beautiful new site and buildings, has grown in equal proportion. The City College is erecting new buildings, and high schools have been established. Our libraries have been consolidated, the building for the great public library is in course of erection and numerous branch libraries have been founded. The American Museum of Natural History has more than quadrupled the value of its buildings and collections, and the Metropolitan Museum of Art has equally increased its galleries and endowment. The Botanical Garden, the Zoölogical Park and the Aquarium have arisen as by miracle. Hospitals, asylums and all kinds of public institutions have increased even more rapidly than the wealth of the city. In spite of Tammany Hall, in spite of reform administrations, our public, educational and scientific institutions have developed in a way that has perhaps never been equalled hitherto or elsewhere.




In this marvelous development there are two failures that we must all regret — one, the stationary condition of our Academy of Sciences, the other, the dispersal of our institutions over such

an area as to detract greatly from their usefulness. All the way from the Battery to the Bronx — some twenty miles as the trolley car goes — separated by almost impassable streets and overshadowed by tenements and apartment houses, our institutions may be found or at least looked for. Fifteen years ago the city had a great opportunity, but no leader being at hand it was lost. The situation of some of our scientific institutions is shown on the one chart; what might have been is shown on the other.

The city could have bought the blocks from the American Museum to the North River for about $10,000,000. These remaining one half park, half the part of Central Park between the American and the Metropolitan Museums might have been used as a site for public buildings without decreasing the




amount of open space, while at the same time greatly increasing its value for all the purposes of a park. The plan shows what might have been done on the west side. The wasteful duplication of libraries and the rest would have been avoided, and there would have been a strengthening through coöperation for which it is not easy to find words. The site of the park and buildings would, of course, have been above the thoroughfares, and all the buildings would have been within five minutes' ride on an underground railway.

The cross arm of Central Park should have extended to the East River, and there should have been a park along the river, facing Blackwell's Island and corresponding to Riverside Park.

Hospitals and eleemosynary institutions could have been built on this arm of the park and facing it, while the various institutions for the defective classes would have been on the islands in the East River. The cross arm of Central Park would always have been near the center of population of the city, and if it had been made a center for its intellectual and higher social life a gain would have resulted which it would scarcely be possible to overestimate. Fifteen years ago this could have been done as far as the west side is concerned with little or no expense to the city; now it would cost $30,000,000. I should gladly expend one third the yearly income of the city for the purpose; as I am helpless and harmless I suppose there is no danger that I shall be put in the institution on Ward's Island.

The atrophied condition of the New York Academy of Sciences is as lamentable as the dispersal of our scientific institutions, but fortunately it is not so irremediable. The university, the library, the museum and the academy are, as I have already said, the four corner-stones of science and culture. They should be parts of one over-institution, and should, in my opinion, be one of the chief cares and adornments of the state, being no less essential than the police or army and the courts. As the institutions of the city can not now be brought together, we must do the best we can to give the Academy the position it should have. It is immaterial whether the institution be called the New York Academy of Sciences or the Scientific Alliance of New York. We must have an institution that will coördinate the scientific work accomplished in the city. We must have a building for our meetings and other work, and should have as part of it or adjacent to it a club-house. The building should be situated near the Museum of Natural History, this being without doubt the most central position. Let us get money from millionaires if we can, but it seems to me that for the honor of the city the building should be built by the city. I see no reason why it should not be part of the American Museum. The large lecture halls could be used in common, and we should need only two or three rooms of moderate size, one seating about a hundred people, for ordinary society meetings, and others for a commit-

tee room and a room for the archives and secretariats of the different societies. The libraries and any collections there may be could with advantage be merged in those of the museum. Such rooms, if part of a wing of the museum, would cost the city perhaps $100,000. Then we should collect one or two hundred thousand dollars for a club-house to be placed across the street.

A few words remain to be said in regard to the functions of an academy of sciences under the conditions that obtain at the beginning of the twentieth century. Libraries, laboratories and museums are no longer our charge. We are primarily guilds of scientific men. The organization of science in America toward which I believe we are moving is this: We shall have a national society for each of the sciences; these societies will be affiliated and will form the American Association for the Advancement of Science, which will hold migratory meetings. Winter meetings will be held in large centers where all the societies will come together, and summer meetings will be held at points of educational and other interest when the societies will scatter somewhat. The council of the American Association composed of delegates from all the societies will be our chief deliberative and legislative body. Our national societies will consist of local sections, and these sections will unite to form an academy of sciences. The men who are in one neighborhood and engaged in the same kind of work are the natural unit. They should unite on the one hand with those in other neighborhoods to form a national society; they should join on the other hand with the men of science of the same neighborhood to form an academy of sciences. This plan of organization may appear to be almost too logical for a world that is somewhat careless of logic, but it is in part already realized. It will in my opinion result as a necessary condition from the state of affairs. Our academy has already contributed to it, and it seems to me that we should continue to do consciously what we have hitherto done rather blindly.

We have two main external functions — our meetings and our publications. For both of these the men of science inter-

ested in the same subjects are the natural group. We neednot increase the number of our sections; but should allow subsections for each of the sciences, letting those who are immediately concerned meet as they find it most advantageous. These groups should maintain their own autonomy, and we should not require the members to join the academy, least of all so long as our present dues are maintained. The academy should provide convenient places for meeting, arrange for joint meetings of several groups, provide general lectures of interest to more than one group, support a club-house, give receptions and exhibitions and the like.

In regard to publications I am somewhat heterodox. Proceedings and transactions were an important function of the academy of the eighteenth century, but there is no longer any excuse for printing researches on utterly diverse subjects in one volume, because the authors happen to be members of the same academy. We might as well make up volumes according to the cranial index of the contributors. The national society for each science should directly or indirectly have charge of the publications in that science. We need in every science: (1) A series of monographs, each of which should be published as a unit, (2) a "Centralblatt" containing abstracts of the literature with a complete bibliography, and (3) a journal for shorter articles, general discussions, critical reviews, etc. The abstracts and bibliography should be an international undertaking, each country contributing its share. What is now printed in the annals, transactions and proceedings of our academies, should be contributed to the series or journals. In the series of psychological monographs, which I am glad to say exists, should, for example, be printed any monographs that are prepared by our members, and if the academy has funds for publication, it should share the expense. These monographs can be parts of our proceedings and can be given to those members who are interested. Their existence will be known to every specialist throughout the world. They will be purchased by individuals and libraries, and will ultimately become self-supporting. It is to be hoped that the academies of the country will unite in a

plan of this character, and that our academy will initiate the movement.

When we review the whole subject of the history and present status of the academy of sciences we must, I think, come to the conclusion that the function of the modern academy is now modest. Libraries, museums, research laboratories, government departments and universities have developed in a way that leaves no excuse for the academy of sciences to attempt competition with them. The university in its modern form seems to me most suitable for the central institution, and when our universities are controlled and supported by the state and when there is only one university in a region, it seems to me that the university should administer the libraries, museums, research laboratories and the like, and that the academy of sciences will be essentially a part of the university. The national and local societies for each branch of science are the natural groups for meetings and discussion and for publication. Membership in an academy as an honor, the presidency as a distinction, foreign members, medals, prizes and the like, seem to me to belong to the childhood of science. So long as we are still in this state let us rejoice in our innocence, but what is charming in the child is intolerable in the man.

Has the academy of sciences then played its part in the world? Must it, like the mastodon and elephant, give way to organisms better suited to a changed environment? I have already indicated that I believe the academy to have important if modest functions, and have stated what I think them to be. They are essentially those of a guild. We need a center in each community for organization and social intercourse. As capitalists unite in corporations and laborers in trades unions, so men of science should unite in their academies. We should not profess unselfish philanthropy, but we may reasonably claim that whatever is accomplished to improve the condition of men of science, to increase their influence or to forward their work is of benefit to the community and for the welfare of society.

J. McKeen Cattell.

# THE ORGANIZATION

OF THE

# NEW YORK ACADEMY OF SCIENCES

ORIGINAL CHARTER, ORDER OF COURT, AMENDED CHARTER, CONSTITUTION, BY-LAWS AND LIST OF MEMBERS

(APPENDIX, VOL. XV, PART 1)

EDITOR
CHARLES LANE POOR

1903

[Annals N. Y. Acad. Sci., Vol. XV, Part I, pp. 109-152, September 2, 1903.

# THE ORGANIZATION OF THE NEW YORK ACADEMY OF SCIENCES.

## THE ORIGINAL CHARTER.

AN ACT TO INCORPORATE THE

LYCEUM OF NATURAL HISTORY IN THE CITY OF NEW YORK.

*Passed April 20, 1818.*

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Whereas, The members of the Lyceum of Natural History have petitioned for an act of incorporation, and the Legislature, impressed with the importance of the study of Natural History, as connected with the wants, the comforts, and the happiness of mankind, and conceiving it their duty to encourage all laudable attempts to promote the progress of science in this State — therefore,

*Be it enacted by the People of the State of New York represented in Senate and Assembly,* That Samuel L. Mitchill, Casper W. Eddy, Frederick C. Schaeffer, Nathaniel Paulding, William Cooper, Benjamin P. Kissam, John Torrey, William Cumberland, D'Jurco V. Knevels, James Clements and James Pierce, and such other persons as now are, and may from time to time become members, shall be, and hereby are constituted a body corporate and politic, by the name of Lyceum of Natural History in the City of New York, and that by that name they shall have perpetual succession, and shall be persons capable of suing and being sued, pleading and being impleaded, answering and being answered unto, defending and being defended, in all courts and places whatsoever; and may have a common seal, with power to alter the same from time to time; and shall be capable of purchasing, taking, holding and enjoying to them and their successors, any real estate in fee simple

or otherwise, and any goods, chattels and personal estate, and of selling, leasing, or otherwise disposing of said real or personal estate, or any part thereof, at their will and pleasure : *Provided always*, that the clear annual value or income of such real or personal estate shall not exceed the sum of five thousand dollars : *Provided*, however, that the funds of the said corporation shall be used and appropriated to the promotion of the objects stated in the preamble to this act, and those only.

2. *And be it further enacted*, That the said Society shall, from time to time, forever hereafter, have power to make, constitute, ordain, and establish such by-laws and regulations as they shall judge proper, for the election of their officers ; for prescribing their respective functions, and the mode of discharging the same ; for the admission of new members ; for the government of the officers and members thereof ; for collecting annual contributions from the members towards the funds thereof ; for regulating the times and places of meeting of the said Society ; for suspending or expelling such members as shall neglect or refuse to comply with the by-laws or regulations, and for the managing or directing the affairs and concerns of the said Society : *Provided* such by-laws and regulations be not repugnant to the Constitution and laws of this State or of the United States.

3. *And be it further enacted*, That the officers of the said Society shall consist of a President and two Vice-Presidents, a Corresponding Secretary, a Recording Secretary, a Treasurer, and five Curators, and such other officers as the Society may judge necessary ; who shall be annually chosen, and who shall continue in office for one year, or until others be elected in their stead ; that if the annual election shall not be held at any of the days for that purpose appointed, it shall be lawful to make such election at any other day ; and that five members of the said Society, assembling at the place and time designated for that purpose by any by-law or regulation of the Society, shall constitute a legal meeting thereof.

4. *And be it further enacted*, That Samuel L. Mitchill shall be the President ; Casper W. Eddy the First Vice-President ; Frederick C. Schaeffer the Second Vice-President ; Nathaniel

Paulding, Corresponding Secretary; William Cooper, Recording Secretary; Benjamin P. Kissam, Treasurer, and John Torrey, William Cumberland, D'Jurco V. Knevels, James Clements and James Pierce, Curators; severally to be the first officers of the said corporation, who shall hold their respective offices until the twenty-third day of February next, and until others shall be chosen in their places.

5. *And be it further enacted*, That the present Constitution of the said Association shall, after passing of this Act, continue to be the Constitution thereof; and that no alteration shall be made therein, unless by a vote to that effect of three-fourths of the resident members, and upon the request in writing of one-third of such resident members, and submitted at least one month before any vote shall be taken thereupon.

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*State of New York, Secretary's Office.*

I CERTIFY the preceding to be a true copy of an original Act of the Legislature of this State, on file in this Office.

ARCH'D CAMPBELL,
*Dep. Sec'y.*

ALBANY, *April 29*, 1818.

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## ORDER OF COURT.

ORDER OF THE SUPREME COURT OF THE STATE OF NEW YORK

TO CHANGE THE NAME OF

THE LYCEUM OF NATURAL HISTORY IN THE CITY OF NEW YORK

TO

THE NEW YORK ACADEMY OF SCIENCES.

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WHEREAS, in pursuance of the vote and proceedings of this Corporation to change the corporate name thereof from "The

Lyceum of Natural History in the City of New York" to "The New York Academy of Sciences," which vote and proceedings appear of record, an application has been made in behalf of said Corporation to the Supreme Court of the State of New York to legalize and authorize such change, according to the statute in such case provided, by Chittenden & Hubbard, acting as the attorneys of the Corporation, and the said Supreme Court, on the 5th day of January, 1876, made the following order upon such application in the premises, viz:

At a special term of the Supreme Court of the State of New York, held at the Chambers thereof, in the County Court House, in the City of New York, the 5th day of January, 1876:

Present — HON. GEO. C. BARRETT, *Justice*.

In the matter of the application of the Lyceum of Natural History in the City of New York to authorize it to assume the corporate name of the New York Academy of Sciences.

On reading and filing the petition of the Lyceum of Natural History in the City of New York, duly verified by John S. Newberry, the President and chief officer of said Corporation to authorize it to assume the corporate name of The New York Academy of Sciences, duly setting forth the grounds of said application, and on reading and filing the affidavit of Geo. W. Quackenbush, showing that notice of such application had been duly published for six weeks in the State paper, to wit, *The Albany Evening Journal*, and the affidavit of David S. Owen, showing that notice of such application had also been duly published in the proper newspaper of the County of New York, in which

county said Corporation has its business office, to wit, in the *Daily Register*, by which it appears to my satisfaction that such notice has been so published, and on reading and filing the affidavits of Robert H. Brownne and J. S. Newberry, thereunto annexed, by which it appears to my satisfaction that the application is made in pursuance of a resolution of the managers of said Corporation to that end named, and there appearing to me to be no reasonable objection to said Corporation so changing its name as prayed in said petition: Now on motion of Grosvenor S. Hubbard, of Counsel for Petitioner, it is

*Ordered*, That the Lyceum of Natural History in the City of New York be and is hereby authorized to assume the corporate name of The New York Academy of Sciences.

Indorsed: Filed January 5, 1876.

A copy. WM. WALSH, *Clerk.*

*Resolution of* THE ACADEMY, *accepting the order of the Court, passed February* 21, 1876.

*And whereas*, The order hath been published as therein required, and all the proceedings necessary to carry out the same have been had, Therefore:

*Resolved*, That the foregoing order be and the same is hereby accepted and adopted by this Corporation, and that in conformity therewith the corporate name thereof, from and after the adoption of the vote and resolution hereinabove referred to, be and the same is hereby declared to be

THE NEW YORK ACADEMY OF SCIENCES.

## THE AMENDED CHARTER.

MARCH 19, 1902.

CHAPTER 181 OF THE LAWS OF 1902.

AN ACT to amend chapter one hundred and ninety-seven of the laws of eighteen hundred and eighteen, entitled "An act to incorporate the Lyceum of Natural History in the City of New York," a corporation now known as the New York Academy of Sciences and to extend the powers of said corporation.

(Became a law March 19, 1902, with the approval of the Governor. Passed, three-fifths being present.)

*The People of the State of New York, represented in Senate and Assembly, do enact as follows:*

SECTION I. The corporation incorporated by chapter one hundred and ninety-seven of the laws of eighteen hundred and eighteen, entitled "An act to incorporate the Lyceum of Natural History in the City of New York," and formerly known by that name, but now known as the New York Academy of Sciences through change of name pursuant to order made by the supreme court at the city and county of New York, on January fifth, eighteen hundred and seventy-six, is hereby authorized and empowered to raise money for, and to erect and maintain, a building in the city of New York for its use, and in which also at its option other scientific societies may be admitted and have their headquarters upon such terms as said corporation may make with them, portions of which building may be also rented out by said corporation for any lawful uses for the purpose of obtaining income for the maintenance of such building and for the promotion of the objects of the corporation; to establish, own, equip, and administer a public library, and a museum having especial reference to scientific subjects; to publish communications, transactions, scientific works, and periodicals; to give scientific instruction by lectures or otherwise; to encourage the advancement of scientific research and discovery, by gifts of money, prizes, or other assistance thereto. The building, or rooms, of said corporation in the city of New York used exclusively for library or scientific purposes shall be

subject to the provisions and be entitled to the benefits of subdivision seven of section four of chapter nine hundred and eight of the laws of eighteen hundred and ninety-six, as amended.

Section II of said chapter one hundred and ninety-seven of the laws of eighteen hundred and eighteen, entitled "An act to incorporate the Lyceum of Natural History in the City of New York," is hereby amended so as to read as follows:

Section II. The said corporation shall from time to time forever hereafter have power to make, constitute, ordain, and establish such by-laws and regulations as it shall judge proper for the election of its officers; for prescribing their respective functions, and the mode of discharging the same; for the admission of new members; for the government of officers and members thereof; for collecting dues and contributions towards the funds thereof; for regulating the times and places of meeting of said corporation; for suspending or expelling such members as shall neglect or refuse to comply with the by-laws or regulations, and for managing or directing the affairs or concerns of the said corporation: and may from time to time alter or modify its constitution, by-laws, rules and regulations.

Section III. Section three of said act is hereby amended so as to read as follows:

The officers of the said corporation shall consist of a president and two or more vice-presidents, a corresponding secretary, a recording secretary, a treasurer, and such other officers as the corporation may judge necessary; who shall be chosen in the manner and for the terms prescribed by the constitution of the said corporation.

Section IV. Section V of said act is hereby amended so as to read as follows:

Section V. The present constitution of the said corporation shall, after the passage of this act, continue to be the constitution thereof until amended as herein provided. Such constitution as may be adopted by a vote of not less than three quarters of such resident members and fellows of the said New York Academy of Sciences as shall be present at a meeting thereof, called by the Recording Secretary for that purpose, within forty

days after the passage of this act, by written notice, duly mailed, postage prepaid, and addressed to each fellow and resident member at least ten days before such meeting, at his last known place of residence, with street and number when known, which meeting shall be held within three months after the passage of this act, shall be thereafter the constitution of the said New York Academy of Sciences, subject to alteration or amendment in the manner provided by such constitution.

A new section is hereby added to said act to be known as Section VI thereof, which shall read as follows:

SECTION VI. The said corporation shall have power to consolidate, to unite, to coöperate, or to ally itself with any other society or association in the city of New York organized for the promotion of the knowledge or the study of any science, or of research therein, and for this purpose to receive, hold, and administer real and personal property for the uses of such consolidation, union, coöperation or alliance, subject to such terms and regulations as may be agreed upon with such associations or societies.

SECTION VI. This act shall take effect immediately.

STATE OF NEW YORK,

OFFICE OF THE SECRETARY OF STATE.

I have compared the preceding with the original law on file in this office, and do hereby certify that the same is a correct transcript therefrom, and the whole of said original law.

Given under my hand and the seal of office of the Secretary of State, at the city of Albany, this eighth day of April, in the year one thousand nine hundred and two.

JOHN T. MCDONOUGH,
*Secretary of State.*

## CONSTITUTION.

ADOPTED, APRIL 24, 1902.

ARTICLE I. The name of this Corporation shall be The New York Academy of Sciences. Its objects shall be the advancement and diffusion of scientific knowledge, and the center of its activities shall be in the City of New York.

ARTICLE II. The Academy shall consist of four classes of members, namely: Active Members, Fellows, Corresponding Members and Honorary Members. Active Members shall be the members of the Corporation who live in or near the City of New York, or who, having removed to a distance, desire to retain their connection with the Academy. Fellows shall be chosen from the Active Members in virtue of their scientific attainments. Corresponding and Honorary Members shall be chosen from among the men of science of the world who have attained distinction as investigators. The number of Corresponding Members shall not exceed two hundred, and the number of Honorary Members shall not exceed fifty.

ARTICLE III. None but Fellows and Active Members who have paid their dues up to and including the last fiscal year, shall be entitled to vote or to hold office in the Academy.

ARTICLE IV. The officers of the Academy shall be a President, as many Vice-Presidents as there are sections of the Academy, a Corresponding Secretary, a Recording Secretary, a Treasurer, a Librarian, an Editor, and six Councillors. The annual election shall be held on the third Monday in December, the officers then chosen to take office at the first meeting in January following.

There shall also be elected at the same time a Finance Committee of three.

ARTICLE V. The officers named in Article IV shall constitute a Council, which shall be the executive body of the Academy with general control over its affairs, including the power to fill *ad interim* any vacancies that may occur in its offices. Past Presidents of the Academy shall be ex-officio members of the Council.

Article VI. The President and Vice-presidents shall not be eligible to more than one reëlection until three years after retiring from office; the Secretaries and Treasurer shall be eligible to reëlection without limitation. The President, Vice-presidents and Secretaries shall be Fellows. The terms of office of Councillors shall be three years, and these officers shall be so grouped that two, at least one of whom shall be a Fellow, shall be elected and two retired each year. Councillors shall not be eligible to reëlection until after the expiration of one year.

Article VII. The election of officers shall be by ballot, and the candidates having the greatest number of votes shall be declared duly elected.

Article VIII. Ten members, the majority of whom shall be Fellows, shall form a quorum at any meeting of the Academy at which business is transacted.

Article IX. The Academy shall establish By-laws, and may amend them from time to time as therein provided.

Article X. This constitution may be amended by a vote of not less than three fourths of the fellows and three fourths of the active members present and voting at a regular business meeting of the Academy, provided that such amendment shall be publicly submitted in writing at the preceding business meeting, and provided also that the Recording Secretary shall send a notice of the proposed amendment at least ten days before the meeting, at which a vote shall be taken, to each fellow and active member entitled to vote.

# BY-LAWS.

Adopted, October 6, 1902.

## Chapter I.

### OFFICERS.

1. *President.* It shall be the duty of the President to preside at the business and special meetings of the Academy; he shall exercise the customary duties of a presiding officer.

2. *Vice-Presidents.* In the absence of the President, the senior Vice-President, in order of Fellowship, shall act as the presiding officer.

3. *Corresponding Secretary.* The Corresponding Secretary shall keep a corrected list of the Honorary and Corresponding Members, their titles and addresses, and shall conduct all correspondence with them. He shall make a report at the Annual Meeting.

4. *Recording Secretary.* The Recording Secretary shall keep the minutes of the Academy proceedings; he shall have charge of all documents belonging to the Academy, and of its corporate seal, which he shall affix and attest as directed by the Council; he shall keep a corrected list of the Active Members and Fellows, and shall send them announcements of the meetings of the Academy; he shall notify all Members and Fellows of their election, and committees of their appointment; he shall give notice to the Treasurer and to the Council of matters requiring their action, and shall bring before the Academy business presented by the Council. He shall make a report at the Annual Meeting.

5. *Treasurer.* The Treasurer shall have charge, under the direction of the Council, of all moneys belonging to the Academy, and of their investment. He shall receive all fees, dues, and contributions to the Academy, and any income that may accrue from property or investment; he shall report to the Council at its last meeting before the Annual Meeting the names of members in arrears; he shall keep the property of

the Academy insured, and shall pay all debts against the Academy the discharge of which shall be ordered by the Council. He shall report to the Council from time to time the state of the finances, and at the Annual Meeting shall report to the Academy the receipts and expenditures for the entire year.

6. *Librarian.* The Librarian shall have charge of the library, under the general direction of the Library Committee of the Council, and shall conduct all correspondence respecting exchanges of the Academy. He shall make a report on the condition of the library at the Annual Meeting.

7. *Editor.* The Editor shall have charge of the publications of the Academy, under the general direction of the Publication Committee of the Council. He shall make a report on the condition of the publications at the Annual Meeting.

## Chapter II.

## COUNCIL.

1. *Meetings.* The Council shall meet once a month, or at the call of the President. It shall have general charge of the affairs of the Academy.

2. *Quorum.* Five members of the Council shall constitute a quorum.

3. *Officers.* The President, Vice-Presidents, and Recording Secretary of the Academy shall hold the same offices in the Council.

4. *Committees.* The Standing Committees of the Council shall be: (1) an Executive Committee consisting of the President, Treasurer, and Recording Secretary; (2) a Committee on Publications; (3) a Committee on the Library, and such other committees as from time to time shall be authorized by the Council. The action of these committees shall be subject to revision by the Council.

## Chapter III.

## FINANCE COMMITTEE.

1. The Finance Committee of the Academy shall audit the

Annual Report of the Treasurer, and shall report on financial questions whenever called upon to do so by the Council.

## Chapter IV.

### ELECTIONS.

1. *Active Members.* (*a*) Active Members shall be nominated in writing to the Council by at least two Active Members or Fellows. If approved by the Council, they may be elected at the succeeding business meeting.

(*b*) Any Active Member who, having removed to a distance from the City of New York, shall nevertheless express a desire to retain his connection with the Academy, may be placed by vote of the Council on a list of Non-resident Members. Such members shall relinquish the full privileges and obligations of Active Members. (Vide Chapters V and X.)

2. *Fellows, Corresponding Members, and Honorary Members.* Nominations for Fellows, Corresponding Members and Honorary Members may be made in writing either to the Recording Secretary or to the Council at its meeting prior to the Annual Meeting. If approved by the Council, the nominees shall then be ballotted for at the Annual Meeting.

3. *Officers.* Nominations for Officers, with the exception of Vice-Presidents, may be sent in writing to the Recording Secretary, with the name of the proposer, at any time not less than thirty days before the Annual Meeting. Each section of the Academy shall nominate a candidate for Vice-President, who, on election, shall be Chairman of the section; the names of such nominees shall be sent to the Recording Secretary properly certified by the sectional secretaries, not less than thirty days before the Annual Meeting. The Council shall then prepare a list which shall be the regular ticket. This list shall be mailed to each Active Member and Fellow at least one week before the Annual Meeting. But any Active Member or Fellow entitled to vote shall be entitled to prepare and vote another ticket.

## Chapter V.

### FEES AND DUES.

1. *Fees and Dues.* Every Active Member shall pay an initiation fee of \$5 within three months after his election, or such election shall be void. The annual dues of Active Members and Fellows shall be \$10, payable in advance at the time of the Annual Meeting; but new members elected after May 1 shall pay \$5 for the remainder of the fiscal year.

Non-resident Members shall be exempt from dues, so long as they shall relinquish the privileges of Active Membership. (Vide Chapter X.)

2. *Members in Arrears.* If any Active Member or Fellow whose dues remain unpaid for more than one year, shall neglect or refuse to pay the same within three months after notification by the Treasurer, his name may be erased from the rolls by vote of the Council. Upon payment of his arrears, however, such person may be restored to Active Membership or Fellowship by vote of the Council.

3. *Renewal of Membership.* Any Active Member or Fellow who shall resign because of removal to a distance from the City of New York, or any Non-resident Member, may be restored by vote of the Council to Active Membership or Fellowship at any time upon application without payment of an initiation fee.

## Chapter VI.

### PATRONS AND LIFE MEMBERS.

1. *Patrons.* Any person contributing at one time \$1,000 to the general funds of the Academy shall be a Patron, and, on election by the Council, shall enjoy all the privileges of Active Members.

2. *Life Members.* Any Active Member or Fellow contributing at one time \$100 to the general funds of the Academy shall be a Life Member, and shall thereafter be exempt from annual dues. Any person becoming a Life Member immediately upon his election as an Active Member shall be exempt from an initiation fee.

## Chapter VII.

### SECTIONS.

1. *Sections.* Sections devoted to special branches of science may be established or discontinued by the Academy on the recommendation of the Council. The present sections of the Academy are the Section of Astronomy, Physics and Chemistry, the Section of Biology, the Section of Geology and Mineralogy, and the Section of Anthropology and Psychology.

2. *Organization.* Each section of the Academy shall have a Chairman and a Secretary, who shall have charge of the meetings of their Section. The regular election of these officers shall take place at the October or November meeting of the section, the officers then chosen to take office at the first meeting in January following.

3. *Affiliation.* Members of scientific societies affiliated with the Academy, and members of the Scientific Alliance, or men of science introduced by members of the Academy, may attend the meetings and present papers under the general regulations of the Academy.

## Chapter VIII.

### MEETINGS.

1. *Business Meetings.* Business meetings of the Academy shall be held on the first Monday of each month from October to May inclusive.

2. *Sectional Meetings.* Sectional meetings shall be held on Monday evenings from October to May inclusive, and at such other times as the Council may determine. The sectional meeting shall follow the business meeting when both occur on the same evening.

3. *Annual Meeting.* The Annual Meeting shall be held on the third Monday in December.

4. *Special Meetings.* A special meeting may be called by the Council, provided one week's notice be sent to each Active Member and Fellow, stating the object of such meeting.

## Chapter IX.

### ORDER OF BUSINESS.

1. *Business Meetings.* The following shall be the order of procedure at business meetings:

1. Minutes of the previous business meeting.
2. Report of the Council.
3. Reports of Committees.
4. Elections.
5. Other business.

2. *Sectional Meetings.* The following shall be the order of procedure at sectional meetings:

1. Minutes of the preceding meeting of the section.
2. Presentation and discussion of papers.
3. Other scientific business.

3. *Annual Meetings.* The following shall be the order of procedure at Annual Meetings:

1. Annual reports of the Corresponding Secretary, Recording Secretary, Treasurer, Librarian, and Editor.
2. Election of Honorary Members, Corresponding Members, and Fellows.
3. Election of officers for the ensuing year.
4. Annual address of the retiring President.

## Chapter X.

### PUBLICATIONS.

1. *Publications.* The established publications of the Academy shall be the *Annals* and the *Memoirs.* They shall be issued by the Editor under the supervision of the Committee on Publications.

2. *Distribution.* One copy of all publications shall be sent to each Patron, Life Member, Active Member and Fellow, *provided*, that upon enquiry by the Editor such Members or Fellows shall signify their desire to receive them.

3. *Publication Fund.* Contributions may be received for the publication fund, and the income thereof shall be applied toward

defraying the expenses of the scientific publications of the Academy.

## Chapter XI.

### GENERAL PROVISIONS.

1. *Debts.* No debts shall be incurred on behalf of the Academy unless authorized by the Council.

2. *Bills.* All bills submitted to the Council must be certified as to correctness by the officers incurring them.

3. *Investments.* All the permanent funds of the Academy shall be invested in United States, or in New York State securities, or in first mortgages on real estate, provided they shall not exceed sixty-five per cent. of the value of the property. All income from patron's fees, life membership fees, and initiation fee shall be added to the permanent fund.

4. *Expulsion, etc.* Any Member or Fellow may be censured, suspended or expelled, for violation of the Constitution or By-Laws, or for any offence deemed sufficient, by a vote of three fourths of the Members and three fourths of the Fellows present at any business meeting, provided such action shall have been recommended by the Council at a previous business meeting, and also, that one month's notice of such recommendation and of the offence charged shall have given the Member accused.

5. *Changes in By-Laws.* No alteration shall be made in these By-Laws unless it should have been submitted publicly in writing at a business meeting, shall have been entered on the Minutes with the names of the Members or Fellows proposing the same, and shall be adopted by two thirds of the Members and Fellows present and voting at a subsequent business meeting.

# LIST OF MEMBERS

OF THE

# NEW YORK ACADEMY OF SCIENCES.

**June 1, 1903.**

## LIST OF FELLOWS AND ACTIVE MEMBERS.

JUNE 1, 1903.

F = Fellows; L = Life Members; P = Patrons.

**Adams, Edward D.** (L.), 455 Madison Avenue.
Adler, J., M.D., 22 East 62d Street.
Allen, J. A. (F.), American Museum of Natural History.
Allis, Edward Phelps, Jr., Ph.D. (F.), Palais Carnoles Mentone, France.
Amend, B. G. (F.), 120 East 19th Street.
Anderson, A. A., 80 West 40th Street.
Andreini, José M., 29 West 75th Street.
Anthony, R. A. (L.), 591 Broadway.
Arnold, E. S. F. (F.), M.D., care of Edward M. Wright, 280 Broadway.
Astor, John Jacob, 23 West 26th Street.

**Bailey, James M.** (L.), 77 Madison Avenue.
Beach, Frederick C., 361 Broadway.
Beard, Daniel C., 204 Amity Street, Flushing, Long Island.
Beck, Fanning, C. T. (F. L.), 78 East 56th Street.
Beers, M. H., 408–410 Broadway.

Berry, Edward W., Haws Building, Passaic, N. J.
Bickmore, Prof. A. S., Ph.D. (F.), American Museum of Natural History.
Bien, Julius, 140 Sixth Avenue.
Bigelow, Maurice A., Ph.D. (F.), Teachers College.
Biggs, Charles, 13 Astor Place.
Blake, Joseph A., M.D. (F.), 437 West 59th Street.
Bliss, Prof. Charles B. (F. L.), Hockanum, Conn.
Boas, Dr. Franz (F.), American Museum of Natural History.
Bolton, H. Carrington, Ph.D. (F. P.), Cosmos Club, Washington, D. C.
Boyd, James, 408 West 26th Street.
Bristol, Prof. Charles L. (F.), University Heights.
Bristol, John I. D., 1 Madison Avenue.
Britton, N. L., Ph.D. (F. P.), N. Y. Botanical Garden, Bronx Park.
Brown, Hon. Addison, LL.D. (F. P.), 45 West 89th Street.
Brown, Alfred S., 160 West 76th Street.
Brown, E. C., 741 St. Nicholas Avenue.
Brownell, Silas B. (F.), 322 West 56th Street.
Bryan, Walter, M.D., 215 St. John's Pl., Brooklyn.
Buchner, Prof. Edw. F. (F.), University of Alabama, University, Ala.
Bumpus, Prof. Herman C. (F.), American Museum of Natural History.
Burnett, Douglass, 42 Livingston Street, Brooklyn, N. Y.
Byrnes, Miss Esther F., Ph.D. (F.), Girls High School, Brooklyn, N. Y.

**Calkins, Prof. Gary N.**, Ph.D. (F.), The Beresford, West 81st Street.
Casey, Major Thomas L., U. S. A. (F. P.), P. O. Drawer 71, St. Louis, Mo.
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## PATRONS.

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## HONORARY MEMBERS.

JUNE 1, 1903.

1887. Agassiz, Alexander. Director Museum Comparative Zoölogy, Harvard University, Cambridge, Mass.

1898. Auwers, Arthur. Professor of Physics and Mathematics, University of Berlin, Berlin, Germany.

1889. Barrois, Charles, M.D. Professor of Geology, University of Lille, President Geological Society of France, Rue Pascal 37 Lille, France.

1898. Brooks, William K. Professor of Invertebrate Zoölogy, Johns Hopkins University, Baltimore, Md.

1887. Dallinger, Rev. Wm. Henry, D.D., D.Sc., D.C.L., LL.D., F.R.S., Ingleside, Lee, London S.E., England.

1899. Darwin, George Howard, M.A., F.R.S., Professor of Astronomy, Trinity College, Cambridge, England.

1876. Dawkins, W. Boyd. Professor of Geology and Paleontology, Victoria University, Owens College, Manchester, England.

1876. Geikie, Sir Archibald, F.R.S. Former Director General of Geological Survey of Great Britain and Ireland, 28 Jermyn Street, London S. W., England.

1889. Gibbs, Wolcott, LL.D. Professor Emeritus of the Application of Science to the Useful Arts, Harvard University, Newport, R. I.

1898. Gill, David, LL.D., F.R.S. His Majesty's Astronomer, Royal Observatory, Cape of Good Hope, Africa.

1889. Goodale, George Lincoln, M.D., LL.D. Professor of Natural History and Botany, Harvard University, Cambridge, Mass.

1894. Haeckel, Ernst, M.D., Ph.D., Sc.D., LL.D. Professor of Zoölogy and Director of Zoölogical Institute in the University of Jena, Jena, Weimar, Germany.

1889. Hall, Asaph. Professor of Mathematics (retired), U. S. Navy, Norfolk, Conn.

1899. Hann, Julius, Ph.D. Professor of Meteorology, University of Vienna, Vienna, Austria.

1864. Hartlaub, Gustav, M.D. Assistant Director, Museum of Natural History, Bremen, Germany.

1898. Hill, Geo. W., LL.D. West Nyack, N. Y.

1896. Hubrecht, Ambrosius, A. W. Professor of Zoölogy and Comparative Anatomy in the University of Utrecht, Utrecht, Netherlands.

1876. Kelvin, The Right Hon. Lord, D.C.L., F.R.S., G.C.V.O. President of the Royal Society of Edinburgh, 28 Chester Square, London, England.

1896. Klein, Felix, Ph.D. Professor of Mathematics in the University of Gottingen, Wilhelm Weber, Strasse 3, Gottingen, Germany.

1876. Lang, Victor E. von. Professor of Physics in the University of Vienna, Secretary Imperial Academy of Sciences, Vienna, Austria.

1887. Langley, Samuel Pierpont, LL.D. Secretary of Smithsonian Institution, Washington, D. C.

1898. Lankester, E. Ray, LL.D., F.R.S. Director British Museum of Natural History, Cromwell Road, S. W., London, England.

1880. Lockyer, Sir Norman, LL.D., F.R.S. Professor of Astronomy in the Royal College of Science, Solar Physics Observatory, South Kensington, England.

1901. Leydig, Prof. Franz von. Professor in the School of Medicine, Bonn, Germany (retired), Wurzburg, Germany.

1898. Moissan, Henri. Professor of Chemistry in the University of Paris, Rue Vauguelin 7, Paris, France.

1898. Nansen, Fridtjof, M.D. Professor of Zoölogy in the Royal Fredericks University, Christiania, Norway.

1891. Newcomb, Simon. Professor of Mathematics (retired), U. S. N., 1620 P Street, Washington, D. C.

1898. Penck, Albrecht. Professor of Geography in the University of Vienna, Vienna, Austria.

1898. Pfeffer, Wm. Professor of Botany in the University of Leipzig, Leipzig, Germany.

1900. Pickering, Edward Charles, LL.D. Paine Professor of Practical Astronomy, Harvard University, Cambridge, Mass.

1900. Poincaré, Jules Henri, F.R.S. Professor of Mathematical Physics, Faculty of Science, Paris, France.

1899. Rayleigh, Lord, LL.D., F.R.S. Professor of Natural Philosophy in the Royal Institution of Great Britain, Albemarle Street, W., London.

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1887. Roscoe, Sir Henry Enfield, D.C.L., LL.D., F.R.S. Vice Chancellor University of London, 10 Braham Gardens, London S. W., England.

1887. Rosenbusch, Karl Henry Ferdinand. Professor of Mineralogy and Geology, University of Heidelberg, Heidelberg, Germany.

1896. Thomson, Joseph John, Sc.D., LL.D., F.R.S. Professor of Experimental Physics in Cambridge University, Cavendish Laboratory, Cambridge, England.

1900. Tylor, Edward Burnett, LL.D., D.C.L., F.R.S. Professor of Anthropology, Balliol College, University of Oxford, Oxford, England.

1878. Young, Charles Augustus, LL.D. Professor of Astronomy in Princeton University, Princeton, N. J.

1898. Zittel, Karl Alfred Ritter von. Professor of Geology and Paleontology in the Royal Bavarian Ludwig-Maximilian University, Munich, Germany.

## CORRESPONDING MEMBERS.

JUNE 1, 1903.

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1883. Abbott, Charles Conrad, M.D. Trenton, N. J.

1883. Acosta, Antonio Gordon y, M.D. President of the Dispensaries of Havana, San Nicolas 54, Havana, Cuba.

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1890. Alexander, Wm. DeWitt. Surveyor General of the Hawaiian Islands, Honolulu, Hawaii.

1899. Andrews, C. W., M.D. Ass't Keeper of Geology, British Museum of Natural History, Cromwell Road, London S. W., Eng.

1876. Appleton, John Howard, M. A. Professor of Chemistry, Brown University, 209 Angell Street, Providence, R. I.

1899. Baker, J. G. Keeper of the Herbariums and the Library, Royal Botanic Gardens, Kew, England.

1898. Balfour, I. B. Professor of Botany in the University of Edinburgh, Edinburgh, Scotland.

1878. Bell, Alexander Graham. President National Geographic Society, Washington, D. C.

1889. Beaumont, J. Vineland, N. J.

1867. Berthoud, Edward L., M.A., M.E. Golden, Jefferson Co., Col.

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1897. Bolton, Herbert, F.R.S.E. Curator and Secretary, Bristol Museum, Bristol, England.

1899. Boltzmann, Ludwig. Professor of Physics in the University of Leipzig, Leipzig, Germany.

1863. Bombicci-Porta, Cav. Com. Louis. Professor of Mineralogy and Applied Geology in the University of Bologna, Bologna, Italy.

1899. Boulenger, G. A. Assistant Keeper in Zoölogy, British Museum of Natural History, London, England.

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1884. Branner, John G., Ph.D., LL.D. Professor of Geology and Vice-President of the Leland Stanford Jr. University, Stanford University, Cal.

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1876. Brush, George Jarvis. Professor of Mineralogy, Yale University, New Haven, Conn.

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1876. Chandler, W. H. Professor of Chemistry, Librarian of Lehigh University, Bethlehem, Pa.

1876. Clarke, Frank Wigglesworth, Chief Chemist U. S. Geological Survey, Washington, D. C.

1891. Clerc, L. Professor of Botany, Ekaterinburg, Russia.

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1877. Crawford, Joseph, Ph.G. 2822 Frankford Avenue, Philadelphia, Pa.

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1870. Dall, Wm. Healey, M.A. Curator Department of Mollusks in the U. S. Nat. Mus., Smithsonian Institution, Washington, D. C.

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1890. Derby, Orville A., F.G.S. Chief of Geographical and Geological Commission, Sao Paulo, Brazil.

1899. Dollo, Louis, Ph.D. Conservateur Musée Royal d'Histoire Naturelle, Brussels, Belgium.

1876. Drown, Thomas Messinger, LL.D. President of Lehigh University, South Bethlehem, Pa.

1868. Duns, J., D.D., F.R.S.E. Professor of Natural Science in College of Edinburgh, Edinburgh, Scotland.

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1880. Elliott, John B. Professor of Theoretical and Practical Medicine in Tulane University, New Orleans, La.

1869. Engelhardt, Francis E., Ph.D. Chemist to Syracuse Board of Health, 7 Clinton Block, Syracuse, N. Y.

1878. Ernst, A., Ph.D. Professor of Natural History in the University of Caracas and Director of Museum, Caracas, Venezuela.

1879. Fairchild, Herman LeRoy, B.S. Professor of Geology in the University of Rochester, Rochester, N. Y.

1887. Fensi, Sebastiana. Florence, Italy.

1879. Fittica, Friedrich Bernhard, Ph.D. Professor of Chemistry in the University of Marburg, Marburg, Germany.

1885. Fletcher, Lazarus, M.A., F.R.S. Keeper of Minerals in the British Museum, 36 Woodville Road, Ealing, London W., England.

1899. Fraas, Eberhard, Ph.D. Trustee of Kgl. Naturalien-Kabinet, Stuttgart, Germany.

1898. Franchet, A., Ph.D. Paris, France.

1879. Fritzgartner, Reinhold, Ph.D., M.E. State Geologist of Honduras, Director National Mint, Tegucigalpa, Honduras.

1870. Gilbert, G. K. Geologist of the U. S. Geological Survey, Washington, D. C.

1858. Gill, Theodore N., M.D. Professor of Zoölogy, Columbian University, Washington, D. C.

1876. Gilman, Daniel C., LL.D. President of the Carnegie Institution, Washington, D. C.

1865. Goessmann, Charles A., Ph.D., LL.D. Professor of Chemistry in the Massachusetts Agricultural College, Amherst, Mass.

1888. Gooch, Frank Austin. Professor of Chemistry in Yale University, New Haven, Conn.

1883. Grattarola, Guiseppe. Professor of Mineralogy, School of Pharmacy, Florence, San Marco, Florence, Italy.

1868. Greenleaf, R. C. Honorary Professor, Military and Public Hygiene in the University of California, care of Surgeon General, U. S. A., Washington, D. C.

1883. Gregorio, Marquis Antonio de, Ph.D. Editor of the Annals of Geol. and Palaeon., Palermo, Sicily, Italy.

1877. Groth, Paul Heinrich. Professor of Mineralogy in the Royal Bayr. Ludwig-Maximilians University, Hamburg, Germany.

1890. Gudeman, Edward, M.D. Associate Professor Classical Philology, University of Pennsylvania, Philadelphia, Pa.

1898. Hale, George E. Professor of Astronomy and Physics in the University of Chicago, Yerkes Observatory, Williams Bay, Wis.

1882. Hesse-Wartegg, Count Ernest von. New York, N. Y.

1867. Hitchcock, C. H., LL.D. Professor of Geology in Dartmouth College, Hanover, N. H.

1900. Holmes, William Henry. Curator U. S. National Museum (Anthropology), Washington, D. C.

1890. Hoskold, H. D., C. et N.E., F.G.S. Director General National Department of Mines and Geology, Santa Fe 2043, Buenos-Ayres, Argentine Republic.

1877. Howard, Thomas D., Jr. Perth Amboy, N. J.

1899. Howes, G. B., LL.D., F.R.S. Professor of Comparative Anatomy, Zoölogy, University of London, London, England.

1876. Hyatt, James, Sc.D. Stanfordville, Duchess Co., N. Y

1896. Iddings, J. P. Professor of Patrology in the University of Chicago, Chicago, Ill.

1875. Iles, Malvern W. Metallurgist, Globe Smelting Co., Denver, Colorado.

1899. Innes, Walter, M.D. School of Medicine, Cairo, Egypt.

1892. Jack, Robert L. Director Geological Survey of Queensland, Brisbane, Queensland.

1899. Jaeckel, Otto, Ph.D. Professor Geology in Koniglichen Museum für Naturkunde, Invalidenstrasse 43, Berlin, Germany.

1883. Jannettaz, Pierre Michel Edouard. Instructor of Geology in School of Architecture, Boulevard Saint Germain 86, Paris, France.

1876. Johnson, Samuel W., M.A. Professor Emeritus of Agricultural Chemistry in Yale University, 24 Turnbull Street, New Haven, Conn.

1876. Jordan, David Starr, M.D., Ph.D., LL.D. President of Leland Stanford Jr. University, Stanford University, California.

1876. Koenig, George A., Ph.D. Professor of Chemistry and Metallurgy in the Michigan College of Mines, Houghton, Mich.

1899. Kohlrausch, Friedrich, Ph.D. (Prof.). President of the Physikalish-Technische Reichsanstalt, Charlottenberg, Marchstrasse 23, Berlin.

1887. Koltzoff-Massalsky, Princess Helene. Florence, Italy.

1890. Kroutschoff, Baron K. de. St. Petersburg, Russia.

1888. Kukio, Baron R. Privy Counsellor and President-General of the Imperial Museum of Japan, Tokio, Japan.

1890. Kulibin, S., M.E. Mining Dept., St. Petersburg, Russia.

1890. Lacroix, Alfred. Professor of Mineralogy in the Museum of Natural History of Paris, Rue Cuvier 57, Paris, France.

1876. Langley, John W., Ph.D. Professor of Electrical Engineering in the Case School of Applied Science, Cleveland, Ohio.

1900. L'apparent, Albert de. Professor of Mineralogy, Geology and Physical Geography, Ecole Libre des Hautes Etudes, Paris, France.

1876. Lattimore, S. A. Professor of Chemistry, in University of Rochester, 271 University Avenue, Rochester, N. Y.

1890. Laussedat, Col. Aimé. Director of the National Conservatory of Arts and Sciences, Rue St. Martin 292, Paris, France.

1876. Le Jolis, Auguste Francois. Directeur de la Societe National des Sci. Nat. et Math. of Cherbourg, Rue de la Duche 29, Cherbourg, France.

1894. Libbey, Wm. Jr. Professor of Physical Geography, Princeton University, Princeton, N. J.

1899. Liversidge, Archibald, Ph.D. Professor of Chemistry, University of Sydney, Sydney, New South Wales.

1869. Mackie, Simon F., M.A. Salt Lake City, Utah.

1876. Macloskie, George. Professor of Biology in Princeton University, Princeton, N. J.

1876. Mallet, John William, M.D., Ph.D., LL.D., F.R.S.

Professor of Chemistry in the University of Virginia, Charlotteville, Va.

1871. Mann, Charles Riborg. Associate in Physics, University of Chicago, Chicago, Ill.

1867. Matthew, George F., Sc.D., LL.D., F.R.S.C. Curator of Natural History Museum Society New Brunswick Museum, St. John N. B., Canada.

1874. Maynard, Charles Johnson. Naturalist of Newton Natural History Society, 477 Crafts Street, West Newton, Mass.

1874. Mead, Theodor Luquer, C.E. Oviedo, Fla.

1888. Meek, Seth E., Curator, Department of Zoology, Field Columbian Museum, Chicago, Ill.

1892. Mendizabal-Temborrel, J. de. Sociedad Alzate, Mexico.

1874. Merriam, Clinton Hart, M.D. Chief of U. S. Biological Survey, Washington, D. C.

1898. Merriman, Mansfield, C.E. Professor of Civil Engineering, Lehigh University, Bethlehem, Pa.

1890. Meyer, A. B., M.D. Director of the Royal Zoological, Anthropological and Ethnological Museum, Dresden, Germany.

1885. Michie, P. S. Professor of Mathematics at the U. S. Military Academy, West Point, N. Y.

1900. Mitsakuri, Kakichi, Ph.D. Professor of Zoology, Imperial University of Tokyo.

1878. Minot, Charles Sedgwick, LL.D. Professor of Histology and Human Embryology in the Harvard Medical School, Boston, Mass.

1876. Mixter, William Gilbert. Professor of Chemistry in the Sheffield Scientific School of Yale University, New Haven, Conn.

1890. Moldehnke, Richard G. G., E.M., Ph.D. Consulting Metallurgist, Box 432, N. Y. City.

1895. Morgan, C. Lloyd, A.M. Professor of Anatomy, University College, Bristol, England.

1864. Morse, Edward S., Ph.D. Director of the Peabody Academy Science, Salem, Mass.

1898. Murray, George R. M., M.C. Keeper of Botany, British Museum, London, England.

Netto, Ladislaus. Professor of Mathematics, Hessische-Ludwigs University, Giessen, Germany.

1866. Newton, Alfred, F.R.S. Professor of Zoölogy and Comparative Anatomy in the University of Cambridge, Magdalen College, Cambridge, England.

1882. Nichols, Henry Alfred Alford, M.D., M.R.C.S. Medical Officer of Public Institutions, Domincia, Br. West Indies.

1884. Nicolis, Enrico de. Professor and Custodian in Museo Civico, Verona, Italy.

1881. Niles, Wm. H. Emeritus Professor of Geology and Geography in Massachusetts Institute of Technology, Boston, Mass.

1880. Nolan, Edward J., M.D. Recording Secretary and Librarian of the Academy Natural Sciences of Philadelphia, Logan Square, Philadelphia, Pa.

1879. Ober, Frederick A. Ornithologist, Smithsonian Institution, Washington, D. C.

1876. Ordway, John M. Professor of Chemistry and Engineering, Tulane University, New Orleans, La.

1898. Ostwald, Wilhelm, Professor of Chemistry, University of Leipzig, Leipzig, Germany.

1866. Packard, Alpheus Spring, M.D. Professor of Zoölogy and Geology, Brown University, 275 Angell Street, Providence, R. I.

1900. Parker, George Howard, Ph.D. Professor of Zoölogy Harvard University, Cambridge, Mass.

1876. Peckham, Stephen F., M.A. Chemist, 286 Broadway, N. Y. City.

1876. Perkins, Maurice F. Professor of Analytical Chemistry Union College, Schenectady, N. Y.

1882. Phené, John Samuel, LL.D. 5 Carlton Terrace, Oakley Street, London, England.

1883. Pisani, F. Professor of Chemistry and Mineralogy in the Naples University, Naples, Italy.

1888. Post, Rev. George E., M.A., M.D. Professor of Surgery in the Syrian College, Beirut, Syria.

1871. Potter, W. B. Mining Engineer, 1225 Spruce Street, St. Louis, Mo.

1894. Poulton, Edward Bagnall. Professor of Zoölogy, Oxford University, Oxford, England.

1876. Prescott, Albert B. Professor of Organic Chemistry and Director of the Chemical Laboratory in the University of Michigan, Ann Arbor, Mich.

1877. Prime, Frederick, Ph.D. Secretary American Philosophical Society, Philadelphia, Pa.

1868. Pumpelly, Raphael. U. S. Geological Survey, Newport, R. I.

1876. Pynchon, Thomas Ruggles, D.D., LL.D. Professor of Moral Philosophy in Trinity College, Hartford, Conn.

1876. Randall, Burton A. Clinical Professor of Ear Diseases, University of Pennsylvania, Philadelphia, Pa.

1888. Reade, T. Mellard, F.G.S. Park Corner, Blundellsands, Liverpool, England.

1876. Remsen, Ira, M.D., Ph.D., LL.D. President of Johns Hopkins University, Baltimore, Md.

1874. Ridgway, Robert. Curator Division of Birds in the U. S. National Museum, Smithsonian Institution, Washington, D. C.

1886. Robb, William L. Professor of Physics in Trinity College, Hartford, Conn.

1879. Russell, Israel Cook, LL.D. Professor of Geology in the University of Michigan, Ann Arbor, Mich.

1876. Sadtler, Samuel P., Ph.D. Professor of Chemistry, Philadelphia College of Pharmacy, Philadelphia, Pa.

1876. Schaeffer, Charles A. President of the University of Iowa, Iowa City, Iowa.

1899. Schlosser, D. Max, Alte Akademie, Munich, Germany.

1867. Schweitzer, Paul, Ph.D., LL.D. Professor of Agricultural Chemistry in the University of Missouri, Columbia, Mo.

1898. Scott, W. B. Professor of Geology, Princeton University, Princeton, N. J.

1876. Scudder, Samuel H., Entomologist and Palaeontologist, Cambridge, Mass.

1894. Sedgwick, W. T. Professor of Biology, Massachusetts Institude of Technology, Boston, Mass.

1876. Sherwood, Andrew. Assistant State Geologist in Second Geological Survey of Pennsylvania, Mansfield, Penn.

1885. Slosson, Charles. Buffalo, N. Y.

1883. Smith, J. Ward. 144 Monmouth Street, Newark, N. J.

1895. Smyth, Charles H., Jr. Professor of Geology and Mineralogy in Hamilton College, Clinton, N. Y.

1890. Spencer, Rev. J. Selden. Tarrytown, N. Y.

1896. Stearns, Robert E. C., Ph.D. Associate in Zoölogy U. S. National Museum, Washington, D. C.

——. Stevens, Walter LeConte. Professor of Physics, Washington and Lee University, Lexington, Va.

1876. Storer, Francis H. Professor of Agricultural Chemistry in Bussey Institute, Harvard University, Jamaica Plain, Mass.

1885. Tagore, Rajah Sir Sourindro Mohun. Mus. Director (Oxon.), Calcutta, India.

1893. Thomson, J. P. President Royal Society of Queensland, Brisbane, Queensland, Australia.

1876. Thurston, Robert Henry. Director Sibley College, Cornell University, Ithaca, N. Y.

1885. Thwing, Rev. Edward P. President of the Western Reserve University, Cleveland, O.

1899. Traquair, R. H. Keeper of Natural History Department of Museum of Science and Art, Edinburgh, Scotland.

1877. Trowbridge, John. Rumford Professor of the Application of Science to Useful Arts in Harvard University, Cambridge, Mass.

1876. Tuttle, D. K. U. S. Mint, Philadelphia, Pa.

1871. Van Hourck, Henri, M.D. Professor of Botany and Director of Botanical Gardens, Rue de la Sante 8, Antwerp, Belgium.

1867. Verrill, Addison Emery. Professor of Zoölogy in Yale University, 86 Whaley Avenue, New Haven, Conn.

1890. Vogdes, Anthony Wayne. Captain 5th U. S. Artillery, Fort Wadsworth, Staten Island, N. Y.

1900. Van Hise, Charles Richard, Ph.D. Professor of Geology, University of Wisconsin, Madison, Wis.

1898. Walcott, Charles Doolittle. Director of the U. S. Geological Survey, Washington, D. C.

1876. Waldo, Leonard. Metallurgist and Electrical Engineer, 71 Broadway, N. Y. City.

1888. Ward, Henry Augustus, LL.D. Rochester, N. Y.

1876. Warring, Charles B., Ph.D. 288 Mill Street, Poughkeepsie, N. Y.

1900. Watase, She, Ph.D. Professor of Histology, Imperial University of Tokyo.

1887. Weber, Thomas. Kelleyville, Ireland.

1883. Weisbach, Albin, Ph.D. Professor of Mineralogy in the School of Mines, Freiberg, Saxony, Germany.

1897. Weller, Stuart, Ph.D. Assistant in Paleontologic Geology, University of Chicago, Chicago, Ill.

1874. White, I. C., Ph.D. State Geologist, Morgantown, W. Va.

1898. Whitman, C. O. Head Professor of Zoology and Director of the Marine Biological Laboratory of the University of Chicago, Chicago, Ill.

1898. Williams, Henry Shaler. Professor of Geology in Yale University, New Haven, Conn.

——. Winchell, N. H., M.A. Professor of Geology in the University of Minnesota, State Geologist, 120 State Street, Minneapolis, Minn.

1866. Wood, Horatio C., M.D., LL.D Professor of Materia Medica University of Pennsylvania, Philadelphia, Pa.

1899. Woodward, A. Smith, M.D. Assistant Keeper of Geology, British Museum of Natural History, London, England.

1869. Woodward, Henry, LL.D., F.R.S. Keeper of Geology in British Museum, 129 Beaufort Street, Chelsea, London S. W., England.

1874. Wright, Albert A. Professor of Geology and Zoölogy in Oberlin College, 123 Forrest Street, Oberlin, O.

1876. Wright, Arthur Williams. Professor of Experimental Physics in Yale University, 73 York Square, New Haven, Conn.

1876. Yarrow, Harry Crecy, M.D. Professor of Dermatology, Columbian University, Washington, D. C.

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OF THE

# NEW YORK ACADEMY OF SCIENCES

[LYCEUM OF NATURAL HISTORY 1818–1876]

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## CONTENTS OF VOL. XV, PART I

# THE ORGANIZATION

OF THE

# NEW YORK

# ACADEMY OF SCIENCES

ORIGINAL CHARTER, ORDER OF COURT, AMENDED
CHARTER, CONSTITUTION, BY-LAWS
AND LIST OF MEMBERS

(APPENDIX, VOL. XV, PART 1)

EDITOR
CHARLES LANE POOR

1903

# THE ORGANIZATION

OF THE

# NEW YORK

# ACADEMY OF SCIENCES

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(APPENDIX, VOL. XV, PART 1)

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EDITOR
CHARLES LANE POOR

1903

# THE ORGANIZATION OF THE NEW YORK ACADEMY OF SCIENCES.

## THE ORIGINAL CHARTER.

AN ACT TO INCORPORATE THE

LYCEUM OF NATURAL HISTORY IN THE CITY OF NEW YORK.

*Passed April 20, 1818.*

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WHEREAS, The members of the Lyceum of Natural History have petitioned for an act of incorporation, and the Legislature, impressed with the importance of the study of Natural History, as connected with the wants, the comforts, and the happiness of mankind, and conceiving it their duty to encourage all laudable attempts to promote the progress of science in this State — therefore,

*Be it enacted by the People of the State of New York represented in Senate and Assembly,* That Samuel L. Mitchill, Casper W. Eddy, Frederick C. Schaeffer, Nathaniel Paulding, William Cooper, Benjamin P. Kissam, John Torrey, William Cumberland, D'Jurco V. Knevels, James Clements and James Pierce, and such other persons as now are, and may from time to time become members, shall be, and hereby are constituted a body corporate and politic, by the name of LYCEUM OF NATURAL HISTORY IN THE CITY OF NEW YORK, and that by that name they shall have perpetual succession, and shall be persons capable of suing and being sued, pleading and being impleaded, answering and being answered unto, defending and being defended, in all courts and places whatsoever; and may have a common seal, with power to alter the same from time to time; and shall be capable of purchasing, taking, holding and enjoying to them and their successors, any real estate in fee simple

or otherwise, and any goods, chattels and personal estate, and of selling, leasing, or otherwise disposing of said real or personal estate, or any part thereof, at their will and pleasure : *Provided always*, that the clear annual value or income of such real or personal estate shall not exceed the sum of five thousand dollars : *Provided*, however, that the funds of the said corporation shall be used and appropriated to the promotion of the objects stated in the preamble to this act, and those only.

2. *And be it further enacted*, That the said Society shall, from time to time, forever hereafter, have power to make, constitute, ordain, and establish such by-laws and regulations as they shall judge proper, for the election of their officers ; for prescribing their respective functions, and the mode of discharging the same ; for the admission of new members ; for the government of the officers and members thereof ; for collecting annual contributions from the members towards the funds thereof ; for regulating the times and places of meeting of the said Society ; for suspending or expelling such members as shall neglect or refuse to comply with the by-laws or regulations, and for the managing or directing the affairs and concerns of the said Society : *Provided* such by-laws and regulations be not repugnant to the Constitution and laws of this State or of the United States.

3. *And be it further enacted*, That the officers of the said Society shall consist of a President and two Vice-Presidents, a Corresponding Secretary, a Recording Secretary, a Treasurer, and five Curators, and such other officers as the Society may judge necessary ; who shall be annually chosen, and who shall continue in office for one year, or until others be elected in their stead ; that if the annual election shall not be held at any of the days for that purpose appointed, it shall be lawful to make such election at any other day ; and that five members of the said Society, assembling at the place and time designated for that purpose by any by-law or regulation of the Society, shall constitute a legal meeting thereof.

4. *And be it further enacted*, That Samuel L. Mitchill shall be the President ; Casper W. Eddy the First Vice-President ; Frederick C. Schaeffer the Second Vice-President ; Nathaniel

Paulding, Corresponding Secretary; William Cooper, Recording Secretary; Benjamin P. Kissam, Treasurer, and John Torrey, William Cumberland, D'Jurco V. Knevels, James Clements and James Pierce, Curators; severally to be the first officers of the said corporation, who shall hold their respective offices until the twenty-third day of February next, and until others shall be chosen in their places.

5. *And be it further enacted*, That the present Constitution of the said Association shall, after passing of this Act, continue to be the Constitution thereof; and that no alteration shall be made therein, unless by a vote to that effect of three-fourths of the resident members, and upon the request in writing of one-third of such resident members, and submitted at least one month before any vote shall be taken thereupon.

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*State of New York, Secretary's Office.*

I CERTIFY the preceding to be a true copy of an original Act of the Legislature of this State, on file in this Office.

ARCH'D CAMPBELL,
*Dep. Sec'y.*

ALBANY, *April 29*, 1818.

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## ORDER OF COURT.

ORDER OF THE SUPREME COURT OF THE STATE OF NEW YORK

TO CHANGE THE NAME OF

THE LYCEUM OF NATURAL HISTORY IN THE CITY OF NEW YORK

TO

THE NEW YORK ACADEMY OF SCIENCES.

---

WHEREAS, in pursuance of the vote and proceedings of this Corporation to change the corporate name thereof from "The

Lyceum of Natural History in the City of New York" to "The New York Academy of Sciences," which vote and proceedings appear of record, an application has been made in behalf of said Corporation to the Supreme Court of the State of New York to legalize and authorize such change, according to the statute in such case provided, by Chittenden & Hubbard, acting as the attorneys of the Corporation, and the said Supreme Court, on the 5th day of January, 1876, made the following order upon such application in the premises, viz:

At a special term of the Supreme Court of the State of New York, held at the Chambers thereof, in the County Court House, in the City of New York, the 5th day of January, 1876:

Present — HON. GEO. C. BARRETT, *Justice*.

In the matter of the application of the Lyceum of Natural History in the City of New York to authorize it to assume the corporate name of the New York Academy of Sciences.

On reading and filing the petition of the Lyceum of Natural History in the City of New York, duly verified by John S. Newberry, the President and chief officer of said Corporation to authorize it to assume the corporate name of The New York Academy of Sciences, duly setting forth the grounds of said application, and on reading and filing the affidavit of Geo. W. Quackenbush, showing that notice of such application had been duly published for six weeks in the State paper, to wit, *The Albany Evening Journal*, and the affidavit of David S. Owen, showing that notice of such application had also been duly published in the proper newspaper of the County of New York, in which

county said Corporation has its business office, to wit, in the *Daily Register*, by which it appears to my satisfaction that such notice has been so published, and on reading and filing the affidavits of Robert H. Brownne and J. S. Newberry, thereunto annexed, by which it appears to my satisfaction that the application is made in pursuance of a resolution of the managers of said Corporation to that end named, and there appearing to me to be no reasonable objection to said Corporation so changing its name as prayed in said petition: Now on motion of Grosvenor S. Hubbard, of Counsel for Petitioner, it is

*Ordered*, That the Lyceum of Natural History in the City of New York be and is hereby authorized to assume the corporate name of The New York Academy of Sciences.

Indorsed: Filed January 5, 1876.

A copy. WM. WALSH, *Clerk.*

*Resolution of* THE ACADEMY, *accepting the order of the Court, passed February* 21, 1876.

*And whereas*, The order hath been published as therein required, and all the proceedings necessary to carry out the same have been had, Therefore:

*Resolved*, That the foregoing order be and the same is hereby accepted and adopted by this Corporation, and that in conformity therewith the corporate name thereof, from and after the adoption of the vote and resolution hereinabove referred to, be and the same is hereby declared to be

THE NEW YORK ACADEMY OF SCIENCES.

## THE AMENDED CHARTER.

MARCH 19, 1902.

CHAPTER 181 OF THE LAWS OF 1902.

AN ACT to amend chapter one hundred and ninety-seven of the laws of eighteen hundred and eighteen, entitled "An act to incorporate the Lyceum of Natural History in the City of New York," a corporation now known as the New York Academy of Sciences and to extend the powers of said corporation.

(Became a law March 19, 1902, with the approval of the Governor. Passed, three-fifths being present.)

*The People of the State of New York, represented in Senate and Assembly, do enact as follows:*

SECTION I. The corporation incorporated by chapter one hundred and ninety-seven of the laws of eighteen hundred and eighteen, entitled "An act to incorporate the Lyceum of Natural History in the City of New York," and formerly known by that name, but now known as the New York Academy of Sciences through change of name pursuant to order made by the supreme court at the city and county of New York, on January fifth, eighteen hundred and seventy-six, is hereby authorized and empowered to raise money for, and to erect and maintain, a building in the city of New York for its use, and in which also at its option other scientific societies may be admitted and have their headquarters upon such terms as said corporation may make with them, portions of which building may be also rented out by said corporation for any lawful uses for the purpose of obtaining income for the maintenance of such building and for the promotion of the objects of the corporation; to establish, own, equip, and administer a public library, and a museum having especial reference to scientific subjects; to publish communications, transactions, scientific works, and periodicals; to give scientific instruction by lectures or otherwise; to encourage the advancement of scientific research and discovery, by gifts of money, prizes, or other assistance thereto. The building, or rooms, of said corporation in the city of New York used exclusively for library or scientific purposes shall be

subject to the provisions and be entitled to the benefits of subdivision seven of section four of chapter nine hundred and eight of the laws of eighteen hundred and ninety-six, as amended.

Section II of said chapter one hundred and ninety-seven of the laws of eighteen hundred and eighteen, entitled "An act to incorporate the Lyceum of Natural History in the City of New York," is hereby amended so as to read as follows:

SECTION II. The said corporation shall from time to time forever hereafter have power to make, constitute, ordain, and establish such by-laws and regulations as it shall judge proper for the election of its officers; for prescribing their respective functions, and the mode of discharging the same; for the admission of new members; for the government of officers and members thereof; for collecting dues and contributions towards the funds thereof; for regulating the times and places of meeting of said corporation; for suspending or expelling such members as shall neglect or refuse to comply with the by-laws or regulations, and for managing or directing the affairs or concerns of the said corporation: and may from time to time alter or modify its constitution, by-laws, rules and regulations.

SECTION III. Section three of said act is hereby amended so as to read as follows:

The officers of the said corporation shall consist of a president and two or more vice-presidents, a corresponding secretary, a recording secretary, a treasurer, and such other officers as the corporation may judge necessary; who shall be chosen in the manner and for the terms prescribed by the constitution of the said corporation.

SECTION IV. Section V of said act is hereby amended so as to read as follows:

SECTION V. The present constitution of the said corporation shall, after the passage of this act, continue to be the constitution thereof until amended as herein provided. Such constitution as may be adopted by a vote of not less than three quarters of such resident members and fellows of the said New York Academy of Sciences as shall be present at a meeting thereof, called by the Recording Secretary for that purpose, within forty

days after the passage of this act, by written notice, duly mailed, postage prepaid, and addressed to each fellow and resident member at least ten days before such meeting, at his last known place of residence, with street and number when known, which meeting shall be held within three months after the passage of this act, shall be thereafter the constitution of the said New York Academy of Sciences, subject to alteration or amendment in the manner provided by such constitution.

A new section is hereby added to said act to be known as Section VI thereof, which shall read as follows:

SECTION VI. The said corporation shall have power to consolidate, to unite, to coöperate, or to ally itself with any other society or association in the city of New York organized for the promotion of the knowledge or the study of any science, or of research therein, and for this purpose to receive, hold, and administer real and personal property for the uses of such consolidation, union, coöperation or alliance, subject to such terms and regulations as may be agreed upon with such associations or societies.

SECTION VI. This act shall take effect immediately.

STATE OF NEW YORK,

OFFICE OF THE SECRETARY OF STATE.

I have compared the preceding with the original law on file in this office, and do hereby certify that the same is a correct transcript therefrom, and the whole of said original law.

Given under my hand and the seal of office of the Secretary of State, at the city of Albany, this eighth day of April, in the year one thousand nine hundred and two.

JOHN T. MCDONOUGH,
*Secretary of State.*

## CONSTITUTION.

Adopted, April 24, 1902.

Article I. The name of this Corporation shall be The New York Academy of Sciences. Its objects shall be the advancement and diffusion of scientific knowledge, and the center of its activities shall be in the City of New York.

Article II. The Academy shall consist of four classes of members, namely: Active Members, Fellows, Corresponding Members and Honorary Members. Active Members shall be the members of the Corporation who live in or near the City of New York, or who, having removed to a distance, desire to retain their connection with the Academy. Fellows shall be chosen from the Active Members in virtue of their scientific attainments. Corresponding and Honorary Members shall be chosen from among the men of science of the world who have attained distinction as investigators. The number of Corresponding Members shall not exceed two hundred, and the number of Honorary Members shall not exceed fifty.

Article III. None but Fellows and Active Members who have paid their dues up to and including the last fiscal year, shall be entitled to vote or to hold office in the Academy.

Article IV. The officers of the Academy shall be a President, as many Vice-Presidents as there are sections of the Academy, a Corresponding Secretary, a Recording Secretary, a Treasurer, a Librarian, an Editor, and six Councillors. The annual election shall be held on the third Monday in December, the officers then chosen to take office at the first meeting in January following.

There shall also be elected at the same time a Finance Committee of three.

Article V. The officers named in Article IV shall constitute a Council, which shall be the executive body of the Academy with general control over its affairs, including the power to fill *ad interim* any vacancies that may occur in its offices. Past Presidents of the Academy shall be ex-officio members of the Council.

Article VI. The President and Vice-presidents shall not be eligible to more than one reëlection until three years after retiring from office; the Secretaries and Treasurer shall be eligible to reëlection without limitation. The President, Vice-presidents and Secretaries shall be Fellows. The terms of office of Councillors shall be three years, and these officers shall be so grouped that two, at least one of whom shall be a Fellow, shall be elected and two retired each year. Councillors shall not be eligible to reëlection until after the expiration of one year.

Article VII. The election of officers shall be by ballot, and the candidates having the greatest number of votes shall be declared duly elected.

Article VIII. Ten members, the majority of whom shall be Fellows, shall form a quorum at any meeting of the Academy at which business is transacted.

Article IX. The Academy shall establish By-laws, and may amend them from time to time as therein provided.

Article X. This constitution may be amended by a vote of not less than three fourths of the fellows and three fourths of the active members present and voting at a regular business meeting of the Academy, provided that such amendment shall be publicly submitted in writing at the preceding business meeting, and provided also that the Recording Secretary shall send a notice of the proposed amendment at least ten days before the meeting, at which a vote shall be taken, to each fellow and active member entitled to vote.

# BY-LAWS.

Adopted, October 6, 1902.

## Chapter I.

### OFFICERS.

1. *President.* It shall be the duty of the President to preside at the business and special meetings of the Academy; he shall exercise the customary duties of a presiding officer.

2. *Vice-Presidents.* In the absence of the President, the senior Vice-President, in order of Fellowship, shall act as the presiding officer.

3. *Corresponding Secretary.* The Corresponding Secretary shall keep a corrected list of the Honorary and Corresponding Members, their titles and addresses, and shall conduct all correspondence with them. He shall make a report at the Annual Meeting.

4. *Recording Secretary.* The Recording Secretary shall keep the minutes of the Academy proceedings; he shall have charge of all documents belonging to the Academy, and of its corporate seal, which he shall affix and attest as directed by the Council; he shall keep a corrected list of the Active Members and Fellows, and shall send them announcements of the meetings of the Academy; he shall notify all Members and Fellows of their election, and committees of their appointment; he shall give notice to the Treasurer and to the Council of matters requiring their action, and shall bring before the Academy business presented by the Council. He shall make a report at the Annual Meeting.

5. *Treasurer.* The Treasurer shall have charge, under the direction of the Council, of all moneys belonging to the Academy, and of their investment. He shall receive all fees, dues, and contributions to the Academy, and any income that may accrue from property or investment; he shall report to the Council at its last meeting before the Annual Meeting the names of members in arrears; he shall keep the property of

the Academy insured, and shall pay all debts against the Academy the discharge of which shall be ordered by the Council. He shall report to the Council from time to time the state of the finances, and at the Annual Meeting shall report to the Academy the receipts and expenditures for the entire year.

6. *Librarian.* The Librarian shall have charge of the library, under the general direction of the Library Committee of the Council, and shall conduct all correspondence respecting exchanges of the Academy. He shall make a report on the condition of the library at the Annual Meeting.

7. *Editor.* The Editor shall have charge of the publications of the Academy, under the general direction of the Publication Committee of the Council. He shall make a report on the condition of the publications at the Annual Meeting.

## Chapter II.

## COUNCIL.

1. *Meetings.* The Council shall meet once a month, or at the call of the President. It shall have general charge of the affairs of the Academy.

2. *Quorum.* Five members of the Council shall constitute a quorum.

3. *Officers.* The President, Vice-Presidents, and Recording Secretary of the Academy shall hold the same offices in the Council.

4. *Committees.* The Standing Committees of the Council shall be : (1) an Executive Committee consisting of the President, Treasurer, and Recording Secretary; (2) a Committee on Publications; (3) a Committee on the Library, and such other committees as from time to time shall be authorized by the Council. The action of these committees shall be subject to revision by the Council.

## Chapter III.

## FINANCE COMMITTEE.

1. The Finance Committee of the Academy shall audit the

Annual Report of the Treasurer, and shall report on financial questions whenever called upon to do so by the Council.

## Chapter IV.

### ELECTIONS.

1. *Active Members.* (*a*) Active Members shall be nominated in writing to the Council by at least two Active Members or Fellows. If approved by the Council, they may be elected at the succeeding business meeting.

(*b*) Any Active Member who, having removed to a distance from the City of New York, shall nevertheless express a desire to retain his connection with the Academy, may be placed by vote of the Council on a list of Non-resident Members. Such members shall relinquish the full privileges and obligations of Active Members. (Vide Chapters V and X.)

2. *Fellows, Corresponding Members, and Honorary Members.* Nominations for Fellows, Corresponding Members and Honorary Members may be made in writing either to the Recording Secretary or to the Council at its meeting prior to the Annual Meeting. If approved by the Council, the nominees shall then be ballotted for at the Annual Meeting.

3. *Officers.* Nominations for Officers, with the exception of Vice-Presidents, may be sent in writing to the Recording Secretary, with the name of the proposer, at any time not less than thirty days before the Annual Meeting. Each section of the Academy shall nominate a candidate for Vice-President, who, on election, shall be Chairman of the section; the names of such nominees shall be sent to the Recording Secretary properly certified by the sectional secretaries, not less than thirty days before the Annual Meeting. The Council shall then prepare a list which shall be the regular ticket. This list shall be mailed to each Active Member and Fellow at least one week before the Annual Meeting. But any Active Member or Fellow entitled to vote shall be entitled to prepare and vote another ticket.

## Chapter V.

### FEES AND DUES.

1. *Fees and Dues.* Every Active Member shall pay an initiation fee of $5 within three months after his election, or such election shall be void. The annual dues of Active Members and Fellows shall be $10, payable in advance at the time of the Annual Meeting; but new members elected after May 1 shall pay $5 for the remainder of the fiscal year.

Non-resident Members shall be exempt from dues, so long as they shall relinquish the privileges of Active Membership. (Vide Chapter X.)

2. *Members in Arrears.* If any Active Member or Fellow whose dues remain unpaid for more than one year, shall neglect or refuse to pay the same within three months after notification by the Treasurer, his name may be erased from the rolls by vote of the Council. Upon payment of his arrears, however, such person may be restored to Active Membership or Fellowship by vote of the Council.

3. *Renewal of Membership.* Any Active Member or Fellow who shall resign because of removal to a distance from the City of New York, or any Non-resident Member, may be restored by vote of the Council to Active Membership or Fellowship at any time upon application without payment of an initiation fee.

## Chapter VI.

### PATRONS AND LIFE MEMBERS.

1. *Patrons.* Any person contributing at one time $1,000 to the general funds of the Academy shall be a Patron, and, on election by the Council, shall enjoy all the privileges of Active Members.

2. *Life Members.* Any Active Member or Fellow contributing at one time $100 to the general funds of the Academy shall be a Life Member, and shall thereafter be exempt from annual dues. Any person becoming a Life Member immediately upon his election as an Active Member shall be exempt from an initiation fee.

## Chapter VII.

### SECTIONS.

1. *Sections.* Sections devoted to special branches of science may be established or discontinued by the Academy on the recommendation of the Council. The present sections of the Academy are the Section of Astronomy, Physics and Chemistry, the Section of Biology, the Section of Geology and Mineralogy, and the Section of Anthropology and Psychology.

2. *Organization.* Each section of the Academy shall have a Chairman and a Secretary, who shall have charge of the meetings of their Section. The regular election of these officers shall take place at the October or November meeting of the section, the officers then chosen to take office at the first meeting in January following.

3. *Affiliation.* Members of scientific societies affiliated with the Academy, and members of the Scientific Alliance, or men of science introduced by members of the Academy, may attend the meetings and present papers under the general regulations of the Academy.

## Chapter VIII.

### MEETINGS.

1. *Business Meetings.* Business meetings of the Academy shall be held on the first Monday of each month from October to May inclusive.

2. *Sectional Meetings.* Sectional meetings shall be held on Monday evenings from October to May inclusive, and at such other times as the Council may determine. The sectional meeting shall follow the business meeting when both occur on the same evening.

3. *Annual Meeting.* The Annual Meeting shall be held on the third Monday in December.

4. *Special Meetings.* A special meeting may be called by the Council, provided one week's notice be sent to each Active Member and Fellow, stating the object of such meeting.

## CHAPTER IX.

### ORDER OF BUSINESS.

1. *Business Meetings.* The following shall be the order of procedure at business meetings:

   1. Minutes of the previous business meeting.
   2. Report of the Council.
   3. Reports of Committees.
   4. Elections.
   5. Other business.

2. *Sectional Meetings.* The following shall be the order of procedure at sectional meetings:

   1. Minutes of the preceding meeting of the section.
   2. Presentation and discussion of papers.
   3. Other scientific business.

3. *Annual Meetings.* The following shall be the order of procedure at Annual Meetings:

   1. Annual reports of the Corresponding Secretary, Recording Secretary, Treasurer, Librarian, and Editor.
   2. Election of Honorary Members, Corresponding Members, and Fellows.
   3. Election of officers for the ensuing year.
   4. Annual address of the retiring President.

## CHAPTER X.

### PUBLICATIONS.

1. *Publications.* The established publications of the Academy shall be the *Annals* and the *Memoirs.* They shall be issued by the Editor under the supervision of the Committee on Publications.

2. *Distribution.* One copy of all publications shall be sent to each Patron, Life Member, Active Member and Fellow, *provided,* that upon enquiry by the Editor such Members or Fellows shall signify their desire to receive them.

3. *Publication Fund.* Contributions may be received for the publication fund, and the income thereof shall be applied toward

defraying the expenses of the scientific publications of the Academy.

## Chapter XI.

### GENERAL PROVISIONS.

1. *Debts.* No debts shall be incurred on behalf of the Academy unless authorized by the Council.

2. *Bills.* All bills submitted to the Council must be certified as to correctness by the officers incurring them.

3. *Investments.* All the permanent funds of the Academy shall be invested in United States, or in New York State securities, or in first mortgages on real estate, provided they shall not exceed sixty-five per cent. of the value of the property. All income from patron's fees, life membership fees, and initiation fee shall be added to the permanent fund.

4. *Expulsion, etc.* Any Member or Fellow may be censured, suspended or expelled, for violation of the Constitution or By-Laws, or for any offence deemed sufficient, by a vote of three fourths of the Members and three fourths of the Fellows present at any business meeting, provided such action shall have been recommended by the Council at a previous business meeting, and also, that one month's notice of such recommendation and of the offence charged shall have given the Member accused.

5. *Changes in By-Laws.* No alteration shall be made in these By-Laws unless it should have been submitted publicly in writing at a business meeting, shall have been entered on the Minutes with the names of the Members or Fellows proposing the same, and shall be adopted by two thirds of the Members and Fellows present and voting at a subsequent business meeting.

# LIST OF MEMBERS

OF THE

# NEW YORK ACADEMY OF SCIENCES.

**June 1, 1903.**

## LIST OF FELLOWS AND ACTIVE MEMBERS.

JUNE 1, 1903.

F = Fellows ; L = Life Members ; P = Patrons.

**Adams, Edward D.** (L.), 455 Madison Avenue.
Adler, J., M.D., 22 East 62d Street.
Allen, J. A. (F.), American Museum of Natural History.
Allis, Edward Phelps, Jr., Ph.D. (F.), Palais Carnoles Mentone, France.
Amend, B. G. (F.), 120 East 19th Street.
Anderson, A. A., 80 West 40th Street.
Andreini, José M., 29 West 75th Street.
Anthony, R. A. (L.), 591 Broadway.
Arnold, E. S. F. (F.), M.D., care of Edward M. Wright, 280 Broadway.
Astor, John Jacob, 23 West 26th Street.

**Bailey, James M.** (L.), 77 Madison Avenue.
Beach, Frederick C., 361 Broadway.
Beard, Daniel C., 204 Amity Street, Flushing, Long Island.
Beck, Fanning, C. T. (F. L.), 78 East 56th Street.
Beers, M. H., 408–410 Broadway.

Berry, Edward W., Haws Building, Passaic, N. J.
Bickmore, Prof. A. S., Ph.D. (F.), American Museum of Natural History.
Bien, Julius, 140 Sixth Avenue.
Bigelow, Maurice A., Ph.D. (F.), Teachers College.
Biggs, Charles, 13 Astor Place.
Blake, Joseph A., M.D. (F.), 437 West 59th Street.
Bliss, Prof. Charles B. (F. L.), Hockanum, Conn.
Boas, Dr. Franz (F.), American Museum of Natural History.
Bolton, H. Carrington, Ph.D. (F. P.), Cosmos Club, Washington, D. C.
Boyd, James, 408 West 26th Street.
Bristol, Prof. Charles L. (F.), University Heights.
Bristol, John I. D., 1 Madison Avenue.
Britton, N. L., Ph.D. (F. P.), N. Y. Botanical Garden, Bronx Park.
Brown, Hon. Addison, LL.D. (F. P.), 45 West 89th Street.
Brown, Alfred S., 160 West 76th Street.
Brown, E. C., 741 St. Nicholas Avenue.
Brownell, Silas B. (F.), 322 West 56th Street.
Bryan, Walter, M.D., 215 St. John's Pl., Brooklyn.
Buchner, Prof. Edw. F. (F.), University of Alabama, University, Ala.
Bumpus, Prof. Herman C. (F.), American Museum of Natural History.
Burnett, Douglass, 42 Livingston Street, Brooklyn, N. Y.
Byrnes, Miss Esther F., Ph.D. (F.), Girls High School, Brooklyn, N. Y.

**Calkins, Prof. Gary N.**, Ph.D. (F.), The Beresford, West 81st Street.
Casey, Major Thomas L., U. S. A. (F. P.), P. O. Drawer 71, St. Louis, Mo.
Caswell, John H. (F.), 11 West 48th Street.
Cattell, Prof. John McK. (F.), Columbia University.
Chamberlain, Rev. L. T., M.D., The Chelsea, 23d Street, bet. 7th and 8th Avenues.

Chandler, Prof. Chas. F., Ph.D., M.D. (F.), Columbia University.
Chapin, Chester W. (P.), 34 West 57th Street.
Chapman, Frank M. (F.), American Museum of Natural History.
Cheesman, Timothy M., M.D. (F.), Garrisons, N. Y.
Collingwood, Francis (F.), Elizabeth, N. J.
Conkling, Hon. Alfred R., 27 East 10th Street.
Constant, S. Victor (L.), 420 West 23d Street.
Cooper, Hon. Edward, 12 Washington Square, N. Y.
Cox, Charles F. (F.), 54 East 67th Street.
Crampton, Prof. Henry E. (F.), Columbia University.
Cunningham, Richard H., M.D. (F.), 200 West 56th Street.
Curtis, Prof. John G., M.D. (F.), 327 West 58th Street.

**Daily, W. H.**, 32 Old Jewry, London, E. C., England.
Davies, Wm. G., 34 Nassau Street.
Davis, Charles H., 99 Cedar Street.
Davis, William H., Columbia University.
Day, Wm. S. (F.), 551 West End Avenue.
Dean, Prof. Bashford, Ph.D. (F.), Columbia University.
Delafield, M. L., Jr. (L.), care of Jos. L. Delafield, 35 Nassau Street.
Devereux, W. B., 99 John Street.
Devoe, F. W., 101 Fulton Street.
DeWitt, W. G., 88 Nassau Street.
Dickerson, Edward N., Washington Life Building, 141 Broadway.
Dix, Rev. Morgan, D.D., 27 West 25th Street.
Dodge, Prof. R. E., M.A. (F.), Teachers College, West 120th Street.
Dodge, Hon. Wm. E. (P.), 262 Madison Avenue.
Donald, James M., Hanover Nat. Bank, 11 Nassau Street.
Doremus, Prof. Chas. A., Ph.D. (F.), 59 West 51st Street.
Doremus, Prof. R. Ogden, M.D. (F.), 241 Madison Avenue.
Douglas, James (L.), 99 John Street.
Douglass, Alfred, 170 West 59th Street.

Draper, Mrs. M. A. P., 271 Madison Avenue.
Drummond, Isaac W., M.D., 436 West 22d Street.
Dudley, P. H. (F.), 80 Pine Street.
Dunham, Edward K., M.D., 338 East 26th Street.
Dutcher, William (F.), 525 Manhattan Ave.
Du Vivier, Charles L., 22 Warren Street.
Dwight, Jonathan, Jr., M.D. (F.), 2 East 34th Street.
Dyar, Harrison G. (F.), U. S. National Museum, Washington, D. C.

**Elliott, Prof. A. H., Ph.D.** (L.), 4 Irving Place.
English, George L., 201 East 16th Street.
Eno, Wm. Phelps, 111 Broadway.
Eyerman, John (F.), Easton, Pa.

**Fargo, James C.**, 56 Park Avenue.
Farmer, Alexander S., 140 Rodney Street, Brooklyn.
Farrand, Prof. Livingston, M.D. (F.), Columbia University.
Field, C. de Peyster (P.), 21 East 26th Street.
Finlay, George I. (F.), Columbia University.
Foley, Ernest, 108 East 62d Street.
Ford, James B. (L.), 4 East 43d Street.
Franklin, Fred. W., 346 Broadway.
Frissell, A. S., 530 Fifth Avenue.

**Gallatin, Frederick**, 670 Fifth Avenue.
Gies, Prof. William J. (F.), 437 West 59th Street.
Gould, Edwin (P.), Dobbs Ferry, N. Y.
Gould, Frank J., Irvington, N. Y.
Gould, George J. (P.), 195 Broadway.
Gould, Miss Helen M. (P.), Irvington, N. Y.
Grabau, Prof. Amadeus W. (F.), Columbia University.
Green, Hon. Andrew H., 214 Broadway.

**Hall, James P.**, Tribune Building, Editorial Rooms.
Hallock, Prof. William (F.), Columbia University.
Havemeyer, William F., 29 West 19th Street.

Hay, O. P., Ph.D. (F.), American Museum of Nat. Hist.
Heller, Max, 312 West 99th Street.
Hering, Prof. Daniel W. (F.), University Heights.
Herrman, Mrs. Esther (P.), 20 West 72d Street.
Herter, Christian A., M.D. (F.), 839 Madison Avenue.
Hewitt, Edward R., Garden City, L. I.
Hinton, John H., M.D. (F. P.), 41 West 32d Street.
Hitchcock, Miss F. R. M., Ph.D. (F.), 4038 Walnut Street, Philadelphia, Pa.
Hitchcock, Romyn, 20 Broad Street.
Hoffman, S. V., Morristown, N. J.
Hollick, Arthur, Ph.D. (F.), N. Y. Botanical Garden, Bronx Park.
Holst, L. J. R., 52 Union Square, E.
Holt, Charles, 255 West 45th Street.
Holt, Henry (L.), 29 West 23d Street.
Hoppin, Wm. W., 111 Broadway.
Hornaday, Wm. T. (F.), 183d Street and Southern Boulevard.
Hovey, Edmund Otis, Ph.D. (F.), Am. Mus. Nat. Hist.
Howe, Prof. Henry M. (F.), Columbia University.
Howe, Marshall A. (F.), N. Y. Botanical Garden, Bronx Park.
Hoyt, Alfred M., 1 Broadway.
Hubbard, Walter C., Room 25, Cotton Exchange.
Huntington, Geo. S., M.D. (F.), 50 East 73d Street.
Hyde, B. Talbot B. (L.), 82 Washington Street.
Hyde, E. Francis, Hotel Netherlands.
Hyde, Fr. E., M.D. (L.), 20 West 53d Street.
Hyde, Henry St. J., 210 East 18th Street.

**Iles, George** (L.), 5 Brunswick Street, Montreal, Can.
Irving, John D., Ph.D. (F.), U. S. Geological Survey, Washington, D. C.

**Jacobi, Abram**, M.D. (F.), 110 West 34th Street.
Jacoby, Prof. Harold (F.), Columbia University.
James, D. Willis, 40 East 39th Street.
Jesup, Morris K., 197 Madison Avenue.

Julien, Alexis A., Ph.D. (F. P.), Columbia University.

**Kane, S. Nicholson,** Knickerbocker Club.
Kemp, Prof. James F. (F. L.), Columbia University.
Kendig, Rev. A. B., 69 Centre Street, Brookline, Mass.
Kennedy, John S., 6 West 57th Street.
Keppler, Rudolph (L.), 28 West 70th Street.
Keyser, Samuel K., 14 East 36th Street.
Kunz, George F. (F.), care of Tiffany & Co., 15 Union Square.

**Lamb, Osborn R.** (L.), 356 West 22d Street.
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Lawton, James M. J. (L.), care of Mr. Joseph Seeley, Produce Exchange Building.
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Ledoux, Albert R., Ph.D. (F.), 99 John Street.
Lee, Prof. Frederic S. (F.), 437 West 59th Street.
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Loeb, Prof. Morris, Ph.D. (F.), 118 West 72d Street.
Loeb, Solomon, 37 East 38th Street.
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Low, Hon. Seth (L.), Columbia University.
Luquer, Lea McL. (F.), Columbia University.
Lusk, Prof. Graham F., N. Y. Univ. and Med. College.
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McMillin, Emerson, 40 Wall Street.
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MacDougall, Prof. Robert (F.), School of Pedagogy, N. Y. University.
MacHaughton, James, 16 Central Park West.
Maitland, Alexander, 45 Broadway.
Marble, Manton, Bedford, Westchester Co., N. Y.
Marston, Edwin S., 291 Clinton Avenue, Brooklyn, N. Y.
Martin, Prof. Daniel S. (F. L.), 756 Quincy Street, Brooklyn, N. Y.
Martin, T. Cumerford (F.), The Monterey, West 114th Street.
Mathew, W. D., Ph.D. (F.), Amer. Mus. Nat. Hist.
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Mayer, Alfred Goldsborough, Ph.D., 34 Plaza Street, Brooklyn.
Mead, Walter H. (P.), 67 Wall Street.
Meltzer, S. J., M.D. (F.), 166 West 126th Street.
Merrill, Fred. J. H. (F.), N. Y. State Museum, Albany, N. Y.
Meyer, Adolph, M.D. (F.), Pathological Institute.
Meyer, Thomas C., Union Club.
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Mitchell, Edward, 31 East 50th Street.
Mitchell, John Murray, 17 Broad Street.
Mitchell, S. Alfred, Ph.D. (F.), Columbia University.
Morgan, J. Pierpont, 219 Madison Avenue.
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Moses, Prof. Alfred J. (F.), Columbia University.
Munsell, C. E., Ph.D., 2110 Horatio Street.

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Olcott, E. E. (L.), 38 West 39th Street.
Osborn, Prof. Henry F., Sc.D., LL.D. (F.), 850 Madison Avenue.

**Parker, Prof. Herschel C.** (F.), Columbia University.
Parsons, John E., 111 Broadway.
Patten, John (L.), 19 Liberty Street.
Peckham, Wheeler H., 685 Madison Avenue.
Pell, Mrs. Alfred, 206 Madison Avenue.
Pellew, Prof. Chas. E. (F.), 68 East 54th Street.
Peterson, Frederic, M.D. (F.), 4 West 50th Street.
Pettigrew, David Lyman, Box 75, Worcester, Mass.
Pfister, J. C. (F.), Columbia University.
Phœnix, Lloyd, 21 East 33d Street.
Pierson, Israel C. (F.), 21 Cortlandt Street.
Piffard, Henry G., M.D. (F.), 256 West 57th Street.
Pitkin, Lucius (F.), 47 Fulton Street.
Poor, Charles Lane, Ph.D. (F.), 4 East 48th Street.
Post, C. A. (F.), 16 Exchange Place.
Post, George B. (F.), 11 West 21st Street.
Prime, Temple (P.), Huntington, L. I.
Prince, Prof. John D. (F.), 31 West 38th Street.
Prudden, Prof. T. Mitchell (F.), 437 West 59th Street.
Pupin, Prof. M. I., Ph.D. (F.), Columbia University.

**Quackenbos, Prof. J. D.**, 331 West 28th Street.

**Rees, Prof. John K.** (F.), Columbia University.
Reuter, L. H., M.D., Merck Building.
Ricketts, Prof. Pierre de P. (F.), 104 John Street.
Riederer, Ludwig, 251 West 95th Street.
Ries, Heinrich (F.), Cornell University, Ithaca, N. Y.
Riley, R. Hudson, Bensonhurst, N. Y.
Robb, Hon. J. Hampden, 23 Park Avenue.
Rogers, Henry H., 26 East 57th Street.
Rusby, Henry H., M.D. (F.), 809 De Graw Avenue, Newark, N. J.
Russak, Frank, 46 Exchange Place.

**Schermerhorn, F. A.** (L.), 61 University Place.
Schuyler, Philip, Nevis, Irvington P. O., N. Y.

Senff, Charles H. (P.), 300 Madison Avenue.
Shiland, Andrew, Jr., 262 West 78th Street.
Shultz, Chas. S., Hoboken, N. J.
Sickles, Ivan, M.D. (F.), 17 Lexington Avenue.
Sieberg, W. H. J., Hotel Winthrop, 7th Ave. and 125th Street.
Sloan, Samuel (P.), 26 Exchange Place.
Smith, Ernest E., M.D., Ph.D., 262 Fifth Avenue.
Starr, Prof. M. Allen (F.), 5 West 54th Street.
Stetson, Francis Lynde (L.), 4 East 74th Street.
Stevens, George T., M.D., 22 East 46th Street.
Stevenson, Prof. J. J. (F. L.), 568 West End Avenue.
Stokes, James, 49 Cedar Street.
Stone, Mason A., 161 Broadway.
Stratford, Prof. Wm., Ph.D. (F.), 17 Lexington Avenue.
Strong, Prof. Chas. A., Ph.D. (F.), Lakewood, N. J., Box 208.
Stuyvesant, Rutherford (F.), 246 East Fifteenth Street.
Sumner, Francis B., Ph.D. (F.), 17 Lexington Avenue.

**Taggart, Rush,** 319 West 75th Street.
Tatlock, John, Jr. (F. L.), P. O. Box 194.
Terry, James (L.), New Haven, Conn.
Thompson, Prof. W. Gilman (F.), 44 East 34th Street.
Thorndike, Edw. L., Ph.D. (F.), Prof., Teachers College.
Townsend, Charles H., New York Aquarium.
Tows, C. D., 34 West 52d Street.
Tripler, Chas. E., 121 West 89th Street.
Trotter, Alfred W. (F.), 71 Broadway.
Trowbridge, Chas. C. (F.), Columbia University.
Tuckerman, Alfred, 1123 Broadway.

**Underwood, Prof. L. M., Ph.D.** (F.), Columbia University.

**Van Beuren, Fred. T.,** 21 West 14th Street.
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van Ingen, Gilbert (F.), N. Y. State Mus., Albany, N. Y.
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Washington, H. S., M.D. (F.), Locust, N. J.
Waterbury, John I., Morristown, N. J.
Whitfield, Prof. R. P. (F.), American Museum of Natural History.
Whitman, Alvord A., 305 West 78th Street.
Wicke, William, 36 East 22d Street.
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Wiggin, Frederick H., 55 West 36th Street.
Wills, Chas. T., 156 Fifth Avenue.
Wilson, Prof. Edmund B., Ph.D., LL.D. (F.), Columbia University.
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Wood, William H. S., 45 East 10th Street.
Woodbridge, Prof. F. J. E. (F.), Columbia University.
Woodward, Prof. R. S. (F.), Columbia University.
Woodhull, Prof. John F., Ph.D. (F.), Teachers College, West 120th Street.
Woodworth, R. S. (F.), N. Y. Univ. Med. College, Bellevue Hospital.
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## PATRONS.

JUNE 1, 1903.

**Bolton, H. Carrington**, Cosmos Club, Washington, D. C.
Britton, Dr. Nathaniel Lord, Director Botanical Garden, Bronx Park, New York City.

**Casey, Major Thomas L.**, P. O. Drawer 71, St. Louis, Mo.
Chapin, Chester W., 34 West 57th Street, New York City.

**Dodge, William E.**, 262 Madison Avenue, New York City.

**Field, C. de Peyster**, 127 Water Street, New York City.

**Gould, Edwin**, Dobbs Ferry, N. Y.
Gould, George J., 195 Broadway.
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Hinton, John H., M.D., 41 West 32d Street, New York City.

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**Mead, Walter H.**, 67 Wall Street, New York City.

**Senff, Charles H.**, 300 Madison Avenue, New York City.
Sloan, Samuel, 26 Exchange Place, New York City.

## HONORARY MEMBERS.

June 1, 1903.

1887. Agassiz, Alexander. Director Museum Comparative Zoölogy, Harvard University, Cambridge, Mass.

1898. Auwers, Arthur. Professor of Physics and Mathematics, University of Berlin, Berlin, Germany.

1889. Barrois, Charles, M.D. Professor of Geology, University of Lille, President Geological Society of France, Rue Pascal 37 Lille, France.

1898. Brooks, William K. Professor of Invertebrate Zoölogy, Johns Hopkins University, Baltimore, Md.

1887. Dallinger, Rev. Wm. Henry, D.D., D.Sc., D.C.L., LL.D., F.R.S., Ingleside, Lee, London S.E., England.

1899. Darwin, George Howard, M.A., F.R.S., Professor of Astronomy, Trinity College, Cambridge, England.

1876. Dawkins, W. Boyd. Professor of Geology and Paleontology, Victoria University, Owens College, Manchester, England.

1876. Geikie, Sir Archibald, F.R.S. Former Director General of Geological Survey of Great Britain and Ireland, 28 Jermyn Street, London S. W., England.

1889. Gibbs, Wolcott, LL.D. Professor Emeritus of the Application of Science to the Useful Arts, Harvard University, Newport, R. I.

1898. Gill, David, LL.D., F.R.S. His Majesty's Astronomer, Royal Observatory, Cape of Good Hope, Africa.

1889. Goodale, George Lincoln, M.D., LL.D. Professor of Natural History and Botany, Harvard University, Cambridge, Mass.

1894. Haeckel, Ernst, M.D., Ph.D., Sc.D., LL.D. Professor of Zoölogy and Director of Zoölogical Institute in the University of Jena, Jena, Weimar, Germany.

1889. Hall, Asaph. Professor of Mathematics (retired), U. S. Navy, Norfolk, Conn.

1899. Hann, Julius, Ph.D. Professor of Meteorology, University of Vienna, Vienna, Austria.

1864. Hartlaub, Gustav, M.D. Assistant Director, Museum of Natural History, Bremen, Germany.

1898. Hill, Geo. W., LL.D. West Nyack, N. Y.

1896. Hubrecht, Ambrosius, A. W. Professor of Zoölogy and Comparative Anatomy in the University of Utrecht, Utrecht, Netherlands.

1876. Kelvin, The Right Hon. Lord, D.C.L., F.R.S., G.C.V.O. President of the Royal Society of Edinburgh, 28 Chester Square, London, England.

1896. Klein, Felix, Ph.D. Professor of Mathematics in the University of Gottingen, Wilhelm Weber, Strasse 3, Gottingen, Germany.

1876. Lang, Victor E. von. Professor of Physics in the University of Vienna, Secretary Imperial Academy of Sciences, Vienna, Austria.

1887. Langley, Samuel Pierpont, LL.D. Secretary of Smithsonian Institution, Washington, D. C.

1898. Lankester, E. Ray, LL.D., F.R.S. Director British Museum of Natural History, Cromwell Road, S. W., London, England.

1880. Lockyer, Sir Norman, LL.D., F.R.S. Professor of Astronomy in the Royal College of Science, Solar Physics Observatory, South Kensington, England.

1901. Leydig, Prof. Franz von. Professor in the School of Medicine, Bonn, Germany (retired), Wurzburg, Germany.

1898. Moissan, Henri. Professor of Chemistry in the University of Paris, Rue Vauguelin 7, Paris, France.

1898. Nansen, Fridtjof, M.D. Professor of Zoölogy in the Royal Fredericks University, Christiania, Norway.

1891. Newcomb, Simon. Professor of Mathematics (retired), U. S. N., 1620 P Street, Washington, D. C.

1898. Penck, Albrecht. Professor of Geography in the University of Vienna, Vienna, Austria.

1898. Pfeffer, Wm. Professor of Botany in the University of Leipzig, Leipzig, Germany.

1900. Pickering, Edward Charles, LL.D. Paine Professor of Practical Astronomy, Harvard University, Cambridge, Mass.

1900. Poincaré, Jules Henri, F.R.S. Professor of Mathematical Physics, Faculty of Science, Paris, France.

1899. Rayleigh, Lord, LL.D., F.R.S. Professor of Natural Philosophy in the Royal Institution of Great Britain, Albemarle Street, W., London.

1898. Reusch, Hans H., M.D. Professor of Geology; Head of Norwegian Geological Investigations, Christiania, Norway.

1887. Roscoe, Sir Henry Enfield, D.C.L., LL.D., F.R.S. Vice Chancellor University of London, 10 Braham Gardens, London S. W., England.

1887. Rosenbusch, Karl Henry Ferdinand. Professor of Mineralogy and Geology, University of Heidelberg, Heidelberg, Germany.

1896. Thomson, Joseph John, Sc.D., LL.D., F.R.S. Professor of Experimental Physics in Cambridge University, Cavendish Laboratory, Cambridge, England.

1900. Tylor, Edward Burnett, LL.D., D.C.L., F.R.S. Professor of Anthropology, Balliol College, University of Oxford, Oxford, England.

1878. Young, Charles Augustus, LL.D. Professor of Astronomy in Princeton University, Princeton, N. J.

1898. Zittel, Karl Alfred Ritter von. Professor of Geology and Paleontology in the Royal Bavarian Ludwig-Maximilian University, Munich, Germany.

## CORRESPONDING MEMBERS.

June 1, 1903.

1883. Abbe, Cleveland. Professor of Meteorology in Columbian University, Editor Monthly Weather Review, Weather Bureau in the Department of Agriculture, Washington, D. C.

1883. Abbott, Charles Conrad, M.D. Trenton, N. J.

1883. Acosta, Antonio Gordon y, M.D. President of the Dispensaries of Havana, San Nicolas 54, Havana, Cuba.

1898. Adams, Frank D. Professor of Geology in McGill University, Montreal, Canada.

1891. Aguilera, Jose G. Escuela de Mineria, Mexico, Mex.

1890. Alexander, Wm. DeWitt. Surveyor General of the Hawaiian Islands, Honolulu, Hawaii.

1899. Andrews, C. W., M.D. Ass't Keeper of Geology, British Museum of Natural History, Cromwell Road, London S. W., Eng.

1876. Appleton, John Howard, M. A. Professor of Chemistry, Brown University, 209 Angell Street, Providence, R. I.

1899. Baker, J. G. Keeper of the Herbariums and the Library, Royal Botanic Gardens, Kew, England.

1898. Balfour, I. B. Professor of Botany in the University of Edinburgh, Edinburgh, Scotland.

1878. Bell, Alexander Graham. President National Geographic Society, Washington, D. C.

1889. Beaumont, J. Vineland, N. J.

1867. Berthoud, Edward L., M.A., M.E. Golden, Jefferson Co., Col.

1883. Bertrand, Emile. Professor of Geology in the Ecole des Mines, Paris, France.

1897. Bolton, Herbert, F.R.S.E. Curator and Secretary, Bristol Museum, Bristol, England.

1899. Boltzmann, Ludwig. Professor of Physics in the University of Leipzig, Leipzig, Germany.

1863. Bombicci-Porta, Cav. Com. Louis. Professor of Mineralogy and Applied Geology in the University of Bologna, Bologna, Italy.

1899. Boulenger, G. A. Assistant Keeper in Zoölogy, British Museum of Natural History, London, England.

1874. Brandegee, T. S. San Diego, California.

1884. Branner, John G., Ph.D., LL.D. Professor of Geology and Vice-President of the Leland Stanford Jr. University, Stanford University, Cal.

1894. Branner, Bohnslor, Ph.D. Professor of Chemistry, Bohemian University, Prague, Bohemia.

1874. Brewster, William. Ornithologist, 145 Brattle Street, Cambridge, Mass.

1899. Brögger, W. C. Professor of Geology and Mineralogy in the Royal Fredericks University, Christiania, Norway.

1876. Brush, George Jarvis. Professor of Mineralogy, Yale University, New Haven, Conn.

1876. Caldwell, George Chapman. Professor of Chemistry in Cornell University, Ithaca, N. Y.

1876. Carmichael, Henry, Ph.D. Analytical Chemist, 12 Pearl Street, Boston, Mass.

1898. Carruthers, Wm. C., M.D. Consulting Botanist Royal Agricultural Society of England, British Museum, London, England.

1898. Chamberlin, T. C. Head Professor of Geology in the University of Chicago, Chicago, Ill.

1876. Chandler, W. H. Professor of Chemistry, Librarian of Lehigh University, Bethlehem, Pa.

1876. Clarke, Frank Wigglesworth, Chief Chemist U. S. Geological Survey, Washington, D. C.

1891. Clerc, L. Professor of Botany, Ekaterinburg, Russia.

1877. Comstock, Theo. B., Sc.D. (President Mining Co.). 535 Stimson Block, Los Angeles, Cal.

1868. Cooke, M. C., M.A. Former Keeper of Herbarium, Royal Botanical Garden, Kew, 53 Castle Road, Kenlish Town N.W., England.

1876. Cornwall, H. B. Professor of Analitical Chemistry and Mineralogy, Princeton University, Princeton, N. J.

1880. Cory, Charles B. Professor of Natural History, Field Columbian Museum, Chicago, Ill., 160 Boylston Street, Boston, Mass.

1877. Crawford, Joseph, Ph.G. 2822 Frankford Avenue, Philadelphia, Pa.

1866. Credner, Hermann, Ph.D. Professor of Geology and Paleontology in the University of Leipzig; Director of Geological Survey of the Kingdom of Saxony, Leipzig, Germany.

1895. Cushing, Henry P. Professor of Geology in Western Reserve University, Adelbert College, Cleveland, O.

1890. D'Achiardi, Antonio, Ph.D. Professor of Mineralogy in the University of Pisa, 12 Via San Martino, Pisa, Italy.

1879. Dale, T. Nelson. Geologist of the U. S. Geological Survey; Instructor in Geology and Botany in Williams College, Williamstown, Mass.

1870. Dall, Wm. Healey, M.A. Curator Department of Mollusks in the U. S. Nat. Mus., Smithsonian Institution, Washington, D. C.

1885. Dana, Edward Salisbury, Ph.D. Professor of Physics in Yale University, 119 Grove Street, New Haven, Conn.

1898. Davis, Wm. M., Sturgis Hooper. Professor of Geology, Harvard University, Cambridge, Mass.

1894. Deane, Ruthven. President Illinois Audubon Society, 30 Michigan Ave., Chicago, Ill.

1899. Depéret, Charles, Ph.D. Professor of Physical Geography in the University of Lyons, Lyons, France.

1890. Derby, Orville A., F.G.S. Chief of Geographical and Geological Commission, Sao Paulo, Brazil.

1899. Dollo, Louis, Ph.D. Conservateur Musée Royal d'Histoire Naturelle, Brussels, Belgium.

1876. Drown, Thomas Messinger, LL.D. President of Lehigh University, South Bethlehem, Pa.

1868. Duns, J., D.D., F.R.S.E. Professor of Natural Science in College of Edinburgh, Edinburgh, Scotland.

1876. Elliot, Henry W. Naturalist and Artist, U. S. Geol. Survey, Lakewood, Cuyahoga County, O.

1880. Elliott, John B. Professor of Theoretical and Practical Medicine in Tulane University, New Orleans, La.

1869. Engelhardt, Francis E., Ph.D. Chemist to Syracuse Board of Health, 7 Clinton Block, Syracuse, N. Y.

1878. Ernst, A., Ph.D. Professor of Natural History in the University of Caracas and Director of Museum, Caracas, Venezuela.

1879. Fairchild, Herman LeRoy, B.S. Professor of Geology in the University of Rochester, Rochester, N. Y.

1887. Fensi, Sebastiana. Florence, Italy.

1879. Fittica, Friedrich Bernhard, Ph.D. Professor of Chemistry in the University of Marburg, Marburg, Germany.

1885. Fletcher, Lazarus, M.A., F.R.S. Keeper of Minerals in the British Museum, 36 Woodville Road, Ealing, London W., England.

1899. Fraas, Eberhard, Ph.D. Trustee of Kgl. Naturalien-Kabinet, Stuttgart, Germany.

1898. Franchet, A., Ph.D. Paris, France.

1879. Fritzgartner, Reinhold, Ph.D., M.E. State Geologist of Honduras, Director National Mint, Tegucigalpa, Honduras.

1870. Gilbert, G. K. Geologist of the U. S. Geological Survey, Washington, D. C.

1858. Gill, Theodore N., M.D. Professor of Zoölogy, Columbian University, Washington, D. C.

1876. Gilman, Daniel C., LL.D. President of the Carnegie Institution, Washington, D. C.

1865. Goessmann, Charles A., Ph.D., LL.D. Professor of Chemistry in the Massachusetts Agricultural College, Amherst, Mass.

1888. Gooch, Frank Austin. Professor of Chemistry in Yale University, New Haven, Conn.

1883. Grattarola, Guiseppe. Professor of Mineralogy, School of Pharmacy, Florence, San Marco, Florence, Italy.

1868. Greenleaf, R. C. Honorary Professor, Military and Public Hygiene in the University of California, care of Surgeon General, U. S. A., Washington, D. C.

1883. Gregorio, Marquis Antonio de, Ph.D. Editor of the Annals of Geol. and Palaeon., Palermo, Sicily, Italy.

1877. Groth, Paul Heinrich. Professor of Mineralogy in the Royal Bayr. Ludwig-Maximilians University, Hamburg, Germany.

1890. Gudeman, Edward, M.D. Associate Professor Classical Philology, University of Pennsylvania, Philadelphia, Pa.

1898. Hale, George E. Professor of Astronomy and Physics in the University of Chicago, Yerkes Observatory, Williams Bay, Wis.

1882. Hesse-Wartegg, Count Ernest von. New York, N. Y.

1867. Hitchcock, C. H., LL.D. Professor of Geology in Dartmouth College, Hanover, N. H.

1900. Holmes, William Henry. Curator U. S. National Museum (Anthropology), Washington, D. C.

1890. Hoskold, H. D., C. et N.E., F.G.S. Director General National Department of Mines and Geology, Santa Fe 2043, Buenos-Ayres, Argentine Republic.

1877. Howard, Thomas D., Jr. Perth Amboy, N. J.

1899. Howes, G. B., LL.D., F.R.S. Professor of Comparative Anatomy, Zoölogy, University of London, London, England.

1876. Hyatt, James, Sc.D. Stanfordville, Duchess Co., N. Y

1896. Iddings, J. P. Professor of Patrology in the University of Chicago, Chicago, Ill.

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1899. Innes, Walter, M.D. School of Medicine, Cairo, Egypt.

1892. Jack, Robert L. Director Geological Survey of Queensland, Brisbane, Queensland.

1899. Jaeckel, Otto, Ph.D. Professor Geology in Koniglichen Museum für Naturkunde, Invalidenstrasse 43, Berlin, Germany.

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1876. Jordan, David Starr, M.D., Ph.D., LL.D. President of Leland Stanford Jr. University, Stanford University, California.

1876. Koenig, George A., Ph.D. Professor of Chemistry and Metallurgy in the Michigan College of Mines, Houghton, Mich.

1899. Kohlrausch, Friedrich, Ph.D. (Prof.). President of the Physikalish-Technische Reichsanstalt, Charlottenberg, Marchstrasse 23, Berlin.

1887. Koltzoff-Massalsky, Princess Helene. Florence, Italy.

1890. Kroutschoff, Baron K. de. St. Petersburg, Russia.

1888. Kukio, Baron R. Privy Counsellor and President-General of the Imperial Museum of Japan, Tokio, Japan.

1890. Kulibin, S., M.E. Mining Dept., St. Petersburg, Russia.

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1876. Langley, John W., Ph.D. Professor of Electrical Engineering in the Case School of Applied Science, Cleveland, Ohio.

1900. L'apparent, Albert de. Professor of Mineralogy, Geology and Physical Geography, Ecole Libre des Hautes Etudes, Paris, France.

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1894. Libbey, Wm. Jr. Professor of Physical Geography, Princeton University, Princeton, N. J.

1899. Liversidge, Archibald, Ph.D. Professor of Chemistry, University of Sydney, Sydney, New South Wales.

1869. Mackie, Simon F., M.A. Salt Lake City, Utah.

1876. Macloskie, George. Professor of Biology in Princeton University, Princeton, N. J.

1876. Mallet, John William, M.D., Ph.D., LL.D., F.R.S.

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1871. Mann, Charles Riborg. Associate in Physics, University of Chicago, Chicago, Ill.

1867. Matthew, George F., Sc.D., LL.D., F.R.S.C. Curator of Natural History Museum Society New Brunswick Museum, St. John N. B., Canada.

1874. Maynard, Charles Johnson. Naturalist of Newton Natural History Society, 477 Crafts Street, West Newton, Mass.

1874. Mead, Theodor Luquer, C.E. Oviedo, Fla.

1888. Meek, Seth E., Curator, Department of Zoology, Field Columbian Museum, Chicago, Ill.

1892. Mendizabal-Temborrel, J. de. Sociedad Alzate, Mexico.

1874. Merriam, Clinton Hart, M.D. Chief of U. S. Biological Survey, Washington, D. C.

1898. Merriman, Mansfield, C.E. Professor of Civil Engineering, Lehigh University, Bethlehem, Pa.

1890. Meyer, A. B., M.D. Director of the Royal Zoological, Anthropological and Ethnological Museum, Dresden, Germany.

1885. Michie, P. S. Professor of Mathematics at the U. S. Military Academy, West Point, N. Y.

1900. Mitsakuri, Kakichi, Ph.D. Professor of Zoology, Imperial University of Tokyo.

1878. Minot, Charles Sedgwick, LL.D. Professor of Histology and Human Embryology in the Harvard Medical School, Boston, Mass.

1876. Mixter, William Gilbert. Professor of Chemistry in the Sheffield Scientific School of Yale University, New Haven, Conn.

1890. Moldehnke, Richard G. G., E.M., Ph.D. Consulting Metallurgist, Box 432, N. Y. City.

1895. Morgan, C. Lloyd, A.M. Professor of Anatomy, University College, Bristol, England.

1864. Morse, Edward S., Ph.D. Director of the Peabody Academy Science, Salem, Mass.

1898. Murray, George R. M., M.C. Keeper of Botany, British Museum, London, England.

Netto, Ladislaus. Professor of Mathematics, Hessische-Ludwigs University, Giessen, Germany.

1866. Newton, Alfred, F.R.S. Professor of Zoölogy and Comparative Anatomy in the University of Cambridge, Magdalen College, Cambridge, England.

1882. Nichols, Henry Alfred Alford, M.D., M.R.C.S. Medical Officer of Public Institutions, Domincia, Br. West Indies.

1884. Nicolis, Enrico de. Professor and Custodian in Museo Civico, Verona, Italy.

1881. Niles, Wm. H. Emeritus Professor of Geology and Geography in Massachusetts Institute of Technology, Boston, Mass.

1880. Nolan, Edward J., M.D. Recording Secretary and Librarian of the Academy Natural Sciences of Philadelphia, Logan Square, Philadelphia, Pa.

1879. Ober, Frederick A. Ornithologist, Smithsonian Institution, Washington, D. C.

1876. Ordway, John M. Professor of Chemistry and Engineering, Tulane University, New Orleans, La.

1898. Ostwald, Wilhelm, Professor of Chemistry, University of Leipzig, Leipzig, Germany.

1866. Packard, Alpheus Spring, M.D. Professor of Zoölogy and Geology, Brown University, 275 Angell Street, Providence, R. I.

1900. Parker, George Howard, Ph.D. Professor of Zoölogy Harvard University, Cambridge, Mass.

1876. Peckham, Stephen F., M.A. Chemist, 286 Broadway, N. Y. City.

1876. Perkins, Maurice F. Professor of Analytical Chemistry Union College, Schenectady, N. Y.

1882. Phené, John Samuel, LL.D. 5 Carlton Terrace, Oakley Street, London, England.

1883. Pisani, F. Professor of Chemistry and Mineralogy in the Naples University, Naples, Italy.

1888. Post, Rev. George E., M.A., M.D. Professor of Surgery in the Syrian College, Beirut, Syria.

1871. Potter, W. B. Mining Engineer, 1225 Spruce Street, St. Louis, Mo.

1894. Poulton, Edward Bagnall. Professor of Zoölogy, Oxford University, Oxford, England.

1876. Prescott, Albert B. Professor of Organic Chemistry and Director of the Chemical Laboratory in the University of Michigan, Ann Arbor, Mich.

1877. Prime, Frederick, Ph.D. Secretary American Philosophical Society, Philadelphia, Pa.

1868. Pumpelly, Raphael. U. S. Geological Survey, Newport, R. I.

1876. Pynchon, Thomas Ruggles, D.D., LL.D. Professor of Moral Philosophy in Trinity College, Hartford, Conn.

1876. Randall, Burton A. Clinical Professor of Ear Diseases, University of Pennsylvania, Philadelphia, Pa.

1888. Reade, T. Mellard, F.G.S. Park Corner, Blundellsands, Liverpool, England.

1876. Remsen, Ira, M.D., Ph.D., LL.D. President of Johns Hopkins University, Baltimore, Md.

1874. Ridgway, Robert. Curator Division of Birds in the U. S. National Museum, Smithsonian Institution, Washington, D. C.

1886. Robb, William L. Professor of Physics in Trinity College, Hartford, Conn.

1879. Russell, Israel Cook, LL.D. Professor of Geology in the University of Michigan, Ann Arbor, Mich.

1876. Sadtler, Samuel P., Ph.D. Professor of Chemistry, Philadelphia College of Pharmacy, Philadelphia, Pa.

1876. Schaeffer, Charles A. President of the University of Iowa, Iowa City, Iowa.

1899. Schlosser, D. Max, Alte Akademie, Munich, Germany.

1867. Schweitzer, Paul, Ph.D., LL.D. Professor of Agricultural Chemistry in the University of Missouri, Columbia, Mo.

1898. Scott, W. B. Professor of Geology, Princeton University, Princeton, N. J.

1876. Scudder, Samuel H., Entomologist and Palaeontologist, Cambridge, Mass.

1894. Sedgwick, W. T. Professor of Biology, Massachusetts Institude of Technology, Boston, Mass.

1876. Sherwood, Andrew. Assistant State Geologist in Second Geological Survey of Pennsylvania, Mansfield, Penn.

1885. Slosson, Charles. Buffalo, N. Y.

1883. Smith, J. Ward. 144 Monmouth Street, Newark, N. J.

1895. Smyth, Charles H., Jr. Professor of Geology and Mineralogy in Hamilton College, Clinton, N. Y.

1890. Spencer, Rev. J. Selden. Tarrytown, N. Y.

1896. Stearns, Robert E. C., Ph.D. Associate in Zoölogy U. S. National Museum, Washington, D. C.

——. Stevens, Walter LeConte. Professor of Physics, Washington and Lee University, Lexington, Va.

1876. Storer, Francis H. Professor of Agricultural Chemistry in Bussey Institute, Harvard University, Jamaica Plain, Mass.

1885. Tagore, Rajah Sir Sourindro Mohun. Mus. Director (Oxon.), Calcutta, India.

1893. Thomson, J. P. President Royal Society of Queensland, Brisbane, Queensland, Australia.

1876. Thurston, Robert Henry. Director Sibley College, Cornell University, Ithaca, N. Y.

1885. Thwing, Rev. Edward P. President of the Western Reserve University, Cleveland, O.

1899. Traquair, R. H. Keeper of Natural History Department of Museum of Science and Art, Edinburgh, Scotland.

1877. Trowbridge, John. Rumford Professor of the Application of Science to Useful Arts in Harvard University, Cambridge, Mass.

1876. Tuttle, D. K. U. S. Mint, Philadelphia, Pa.

1871. Van Hourck, Henri, M.D. Professor of Botany and Director of Botanical Gardens, Rue de la Sante 8, Antwerp, Belgium.

1867. Verrill, Addison Emery. Professor of Zoölogy in Yale University, 86 Whaley Avenue, New Haven, Conn.

1890. Vogdes, Anthony Wayne. Captain 5th U. S. Artillery, Fort Wadsworth, Staten Island, N. Y.

1900. Van Hise, Charles Richard, Ph.D. Professor of Geology, University of Wisconsin, Madison, Wis.

1898. Walcott, Charles Doolittle. Director of the U. S. Geological Survey, Washington, D. C.

1876. Waldo, Leonard. Metallurgist and Electrical Engineer, 71 Broadway, N. Y. City.

1888. Ward, Henry Augustus, LL.D. Rochester, N. Y.

1876. Warring, Charles B., Ph.D. 288 Mill Street, Poughkeepsie, N. Y.

1900. Watase, She, Ph.D. Professor of Histology, Imperial University of Tokyo.

1887. Weber, Thomas. Kelleyville, Ireland.

1883. Weisbach, Albin, Ph.D. Professor of Mineralogy in the School of Mines, Freiberg, Saxony, Germany.

1897. Weller, Stuart, Ph.D. Assistant in Paleontologic Geology, University of Chicago, Chicago, Ill.

1874. White, I. C., Ph.D. State Geologist, Morgantown, W. Va.

1898. Whitman, C. O. Head Professor of Zoology and Director of the Marine Biological Laboratory of the University of Chicago, Chicago, Ill.

1898. Williams, Henry Shaler. Professor of Geology in Yale University, New Haven, Conn.

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1866. Wood, Horatio C., M.D., LL.D Professor of Materia Medica University of Pennsylvania, Philadelphia, Pa.

1899. Woodward, A. Smith, M.D. Assistant Keeper of Geology, British Museum of Natural History, London, England.

1869. Woodward, Henry, LL.D., F.R.S. Keeper of Geology in British Museum, 129 Beaufort Street, Chelsea, London S. W., England.

1874. Wright, Albert A. Professor of Geology and Zoölogy in Oberlin College, 123 Forrest Street, Oberlin, O.

1876. Wright, Arthur Williams. Professor of Experimental Physics in Yale University, 73 York Square, New Haven, Conn.

1876. Yarrow, Harry Crecy, M.D. Professor of Dermatology, Columbian University, Washington, D. C.

VOL. XV PART II

# ANNALS

OF THE

# NEW YORK

# ACADEMY OF SCIENCES

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Editor:

CHARLES LANE POOR

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The New Era Printing Company

Lancaster, Pa.

# NEW YORK ACADEMY OF SCIENCES

OFFICERS, 1904

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## SESSION OF 1904

The Academy will meet on Monday evenings at 8.15 o'clock, from October to May, in the American Museum of Natural History, **77th Street and Central Park, West.**

[Annals N. Y. Acad. Sci., Vol. XV, No. 2, pp. 153–215, May 16, 1904.]

# RECORD OF MEETINGS

OF THE

# NEW YORK

# ACADEMY OF SCIENCES

JANUARY TO DECEMBER, 1903

HENRY E. CRAMPTON

*Recording Secretary*

Press of
The New Era Printing Company,
Lancaster, Pa.

[Annals N. Y. Acad. Sci., XV, No. 2, pp. 153–215, May 16, 1904.]

# RECORD OF MEETINGS

OF THE

# NEW YORK ACADEMY OF SCIENCES.

**January to December, 1903.**

Henry E. Crampton, *Recording Secretary.*

## BUSINESS MEETING.

January 5, 1903.

The Academy met at 8:15 P. M., President Cattell presiding. In the absence of the Recording Secretary the reading of the minutes of the preceding business meeting was omitted.

The following candidates for active membership, approved by the Council, were duly elected:

Frederick J. E. Woodbridge, Columbia University.

Edward Phelps Allis, Jr., Mentone, France.

The Academy then adjourned.

J. McKeen Cattell,
*Acting-Secretary, pro tem.*

## SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

JANUARY 5, 1903.

Section met at 8:15 P. M., Professor Charles Lane Poor presiding.

The minutes of the last meeting of the Section were read and approved.

The following program was then offered :

**Harold Jacoby,** COMPARISON OF ASTRO-PHOTOGRAPHIC MEASURES MADE WITH THE RÉSEAU AND WITHOUT IT.

**C. C. Trowbridge,** SOME FACTS REGARDING PERSISTENT METEOR TRAILS — THE SIGNIFICANCE OF SIZE, COLOR AND DRIFT.

SUMMARY OF PAPERS.

Professor Jacoby's paper was as follows :

The *réseau* method of measuring stellar photographs, as considered in the present paper, is similar to that in use in the observatories participating in the photographic survey of the heavens now in progress. The most important advantage of this method of measurement is that it avoids almost altogether the effects of possible contractions or expansions of the sensitive film during development ; and to this advantage has been joined another of a practical character which was perhaps not foreseen by the originators of the *réseau* method. It is found most confusing to measure plates having nothing on their surfaces but star-images ; in fact, in the case of close clusters, it is well-nigh impossible on such plates to make sure that the pairs of coördinates assigned to any star really belong to the same object. All this possibility of confusion disappears, however, with *réseau* plates, as it is easy to keep all measures in order by considering each little square by itself.

As usual, there are compensating disadvantages connected with using the *réseau.* It is necessary, for instance, to make certain assumptions, such as the following :

1. That the division errors of the original *réseau* can be determined as accurately as those of a scale.

2. That the photographic copy of the *réseau*, as it appears on the star-plate, really reproduces exactly the division errors of the original.

3. That the bisection of photographed *réseau* lines on a star-plate can be made with a microscope as accurately as the lines of a scale can be bisected.

It is of course possible to discuss each of these assumptions separately; but in the present note I shall consider one simple experiment only. This consisted in measuring a couple of Pleiades photographs twice, once by the *réseau* method, and once with a metallic scale. A simple comparison ought then to show how far the two methods of measurement differ in their results. Seventy-five stars were observed in each case, and the same stars were used. The first plate was made at Paris, 1901, January 14, and the "probable discordance" between the two methods of measurement was $\pm 0''.11$. No corrections were applied for possible division errors of the Paris *réseau*, as none have been published, though the MM. Henry have satisfied themselves that the Paris *réseau* errors are inappreciable. The second plate was made at Helsingfors, 1900, Dec. 12, and gave a probable discordance of $\pm 0''.22$. In this case the *réseau* measures were corrected with Donner's division errors; but these are not large enough to affect the result appreciably. In both cases, measures made with the metallic scale were corrected for the division errors determined at Columbia University. The larger discordance in the case of the Helsingfors plate is probably due to the less well defined character of the photographed *réseau* lines. In many cases it is impossible to bisect these lines under the microscope anywhere except at the corners of the squares, where two lines cross and form a point.

But when we consider that the above discordances involve the errors of both measurements, they do not appear unduly large. Divided by $\sqrt{2}$, they give for the probable error of a measurement by one method only $\pm 0''.08$ for Paris, and $\pm 0''.16$ for Helsingfors; and there is no evidence of a systematic arrangement of signs in the differences between the two methods.

We may conclude, therefore, that plates measured by the *réseau* method and without it give identical results within a very narrow margin ; nor does irregular distortion of the film appear to have affected appreciably the measures made without the *réseau*.

Mr. **Trowbridge's** paper was a continuation of the results read before the Academy at the meeting on March 3, 1902.

S. A. MITCHELL,
*Secretary*.

## SECTION OF BIOLOGY.

JANUARY 12, 1903.

Section met at 8:15 P. M., Professor Bashford Dean presiding. The minutes of the last meeting of Section were read and approved.

The following program was then offered :

**Gary N. Calkins,** PROTOPLASMIC OLD AGE.

**A. G. Mayer,** THE DRY TORTUGAS AS A BIOLOGICAL STATION FOR RESEARCH.

SUMMARY OF PAPERS.

The paper by Dr. **Calkins** was based upon his studies of *Paramœcium*, individuals of which were isolated in February, 1901, and their descendants kept under observation for 23 months when the series ended by the death of all individuals of the 742d generation. It was pointed out that in the course of the 742 generations there were four well-marked periods of depression or "old age" ; and the accompanying cytological changes, reproductive conditions, and the effects of stimuli were described and discussed.

The paper by Dr. **Mayer** showed the advantages of the Dry Tortugas for biological research. With the aid of lantern illustrations, Dr. Mayer described the favorable conditions with reference to geographical position in relation to ocean currents, the topography, and the nature of the fauna and flora. The complete paper has been prepared for publication in *Science*.

Dr. **Piffard** exhibited a set of X-ray photographs of gastropod shells, designed to obviate the sectioning of rare specimens.

M. A. BIGELOW,
*Secretary*.

## SECTION OF GEOLOGY AND MINERALOGY.

January 19, 1903.

The section met at 8:15, Vice-President Kemp presiding. The minutes of the last meeting were read and approved.

Mr. **George B. Hollister** gave a description of "The Hydrographic Work of the United States Geological Survey," illustrated by lantern-slides and apparatus. After a short discussion of the paper, the thanks of the section were offered Mr. Hollister and the section adjourned.

Alexis A. Julien,
*Secretary, pro tem.*

## SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

January 26, 1903.

The section met in conjunction with the American Ethnological Association, Professor Thorndike presiding.

The following program was offered:

**Maurice Fishberg,** The Ancient Semites and the Modern Jews.

**H. H. St. Clair, 2d,** Investigations among the Comanche and Ute Indians.

Summary of Papers.

Dr. **Fishberg's** paper was as follows:

The somatic characteristics of the ancient and the modern Semites were discussed in detail, the purest representatives of the latter being the Arabian Bedouins. Their anthropological type is distinctly African. The bas-reliefs of the ancient Semites, as represented on the Assyrian and Egyptain monuments, are of the same type. The modern Jews are, on the other hand, a distinctly Asiatic type physically; they are brachycephalic — cephalic index 82 with less than five per cent. of heads having an index of 75 or less. Their head form shows very little variability, but one important feature is that in countries where the non-Jewish population is round-headed the Jews are also round-headed. In Caucasia their cephalic index is 87; in eastern Europe, where the cephalic index of the

non-Jews ranges between 80 and 84, that of the Jews is about the same. In Africa, among the long-headed Gentile population, the Jews are also dolichocephalic. The same is observed to be the case with stature. The Jews are taller in countries where the general population is tall. The type of the Jew is dark, but 12 per cent. of pure-blood types, having fair hair and blue eyes, are to be found. The nose of the modern Jew is not as frequently hooked as is generally supposed. Statistics show that only 12 per cent. are of this variety. The only characteristic which often betrays a Jew is the "Ghetto eye." But such Jews who have lived outside of the pale of the Ghetto for a few generations do not present this phenomenon. Physically there are two types of Jews — one derived from Asia, commonly called *Ashkenasim*, and constituting more than 90 per cent. of the modern Jewery. It has no relation at all with the second type, of African origin, commonly referred to as *Sephardim*. These, constituting less than 10 per cent. of the Jews, alone are more or less related to the ancient Semites, although they have not everywhere preserved themselves as pure as in Africa. Besides these there are to be discerned other subtypes, in which Teutonic, Slavonic and Mongolian blood appears most prominent. From the standpoint of physical anthropology, the view that all the modern Jews are descendants of Abraham, Isaac and Jacob, cannot be seriously considered. The only thing which binds the modern Jews together is their religion. In blood there is no more relation between the Jews than there is between the people who profess the Protestant, Methodist or Unitarian religion.

Mr. **St. Clair's** paper was as follows: The investigations were made during the summer of 1902 upon the Comanches on the Kiowa-Comanche Reservation, Oklahoma, and the Utes of the Uintah Reservation, Utah. Both tribes belong to the great Shoshonean family. These tribes have a very loose social organization and no elaborate religious ceremonial. There are no calendar-records nor any traces of heraldry among the Comanches. The designs painted on rawhide bags or woven in beads have no meaning as with the Shoshones, but are

merely ornamental, and there is lack of the symbolic conversationalism found among such people as the Arapahoes and Sioux. In their stories the coyote figures as the most frequent character representing the fool and schemer. There are striking similarities between the Shoshone and Nahuatl languages of Mexico, each using the same grammatical processes in its pronoun, noun, preposition and verb, and the order of words and structure of the sentence being practically the same in both.

James E. Lough,
*Secretary.*

## BUSINESS MEETING.

February 2, 1903.

The Academy met at 8:15 P. M., Professor William Hallock presiding. The reading of the minutes of the previous business meeting was dispensed with.

No business was presented by the Council.

Adjourned.

Henry E. Crampton,
*Recording Secretary.*

## SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

February 2, 1903.

Section met at 8:15 P. M., Professor Wm. Hallock presiding. The minutes of the last meeting of Section were read and approved.

The following program was then offered:

**Herschel C. Parker,** Experiments Concerning very Brief Electrical Contacts.

**Marston T. Bogert,** Some Products Derived from Coal (illustrated by samples).

### Summary of Papers.

Mr. **Parker's** paper was as follows: A series of electrical contacts giving a fairly accurate range of adjustment from 0.1 second to 0.00001 second would furnish a valuable means of

investigation. A gravity contact key devised by Dr. Charles Forbes gives promise of fulfilling the above conditions. Many determinations were made of the times of contact given by the various devices employed on this key, and also investigations carried out on the times of contact of several forms of pendulum.

The method employed was as follows: A condenser of known capacity ($F$ farads) was charged during the time of contact ($T$), and the deflection on discharging noted. The condenser is again charged through a resistance ($R$) and the deflection ($Q$) observed.

Then;

$$Q = EF \times (1 - e - T/RF)$$

and,

$$T = - RF \times \log e (1 - Q/EF).$$

The "gravity key" consists essentially of a rectangular weight falling on metal guides, the key being furnished with a scale divided in fractions of a second, according to the law of falling bodies, and the weight actuating the various forms of switches employed. If two switches are used, one to make the contact and the other to break the contact, by placing them at different distances apart on the scale, times of contact varying from 0.4 second to 0.001 second may be obtained. For shorter times a single switch that makes and breaks the contact is made use of, and the time made faster or slower by placing in different positions on the scale so that the falling weight strikes it with varying velocities.

In one form the weight moves the short arm of a lever, the long arm passing over a contact strip. Another form is one in which the fulcrum of the lever changes, first giving contact and then breaking the circuit immediately afterwards. In still another type the falling weight strikes a lever arm and releases a spring, which makes the contact, and a further motion of the lever breaks the contact, thus giving a differential effect between the velocity of the weight and the rapidity of the spring. With this key it is possible to obtain a contact of only 0.000017 second and with careful adjustment it seems possible to reach 0.00001 second.

Experiments made with pendulums consisting of a steel ball suspended by a wire, and striking against a steel anvil, gave very positive and satisfactory contacts. Using a pendulum with the suspension wire about four meters long and the steel ball two inches in diameter, an arc, of .5° gave 0.00039 second, while a pendulum with a short suspension wire using one-half-inch steel ball, through an arc of 90° gave 0.000079 second.

It is interesting to note that in working with condensers the best mica condenser gives no appreciable variation in capacity for the very briefest times of charge, while a paraffine condenser may show a reduction in capacity of some sixty per cent. from a time charge of 0.4 second to that of 0.001 second.

Professor Bogert's talk was a very interesting discussion of "Some Products Derived from Coal," paying special reference to the products from coal tar. From bituminous coal by distillation are derived (1) coal gas, (2) ammonia water, (3) tar and (4) coke.

The uses of coal gas and coke are so well known as to need no mentioning. In the United States the total production of ammonium compounds for the year 1900 amounted to 27,000 tons, valued at about $2,000,000.

The chief source of coal tar is the coal gas manufacture, but large amounts are also obtained from the by-product coke ovens, the water gas industry, etc. During the year 1900, 20 per cent. of the gas produced in the United States was coal gas, requiring the distillation of 1,350,000 tons of coal, and producing 13.5 billion cubic feet of gas, *i. e.*, 10,000 cubic feet per ton of coal. The yield of tar is approximately 5 per cent. of the weight of the coal used; the product of tar was therefore, 67,000 tons. If we add to this the 52,500 tons of tar from the by-product coke ovens, we have a total of about 120,000 tons of tar produced in 1900 from coal. This is less than one fifth of the amount produced in England from similar sources. The total production of coal tar in Europe for the year 1898 was 1,120,000 tons.

Coal tar is first roughly divided into the following fractions

1. First runnings, or light oil (lighter than water).

2. Middle oil, or carbolic oil.
3. Heavy oil, dead oil, or creosote oil.
4. Anthracene oil or green grease.
5. Pitch (remains in the stills).

These five products were taken up in detail, and about one hundred drugs, perfumes, etc. were exhibited, the method of derivation of the substances being explained.

S. A. MITCHELL,
*Secretary.*

## SECTION OF BIOLOGY.

FEBRUARY 9, 1903.

Section met at 8:15 P. M at the American Museum, Vice-President Dean presiding. The minutes of the last meeting were read and approved.

The following program was offered:

**W. A. Cannon,** CYTOLOGICAL STUDIES OF VARIATION IN HYBRIDS.

**Bashford Dean**, PAST AND PRESENT STUDY OF ZOÖLOGY IN JAPAN.

**H. F. Osborn,** ON THE PRIMARY DIVISIONS OF THE REPTILIA INTO TWO SUBCLASSES.

### SUMMARY OF PAPERS.

Dr. **Cannon's** paper, was based upon his studies of hybrids of cotton plants, and discussed the relation between the maturation mitoses in hybrids and the variation of the hybrid race. Two forms of mitosis occur in fertile hybrids. One of these is the normal type, which occurs in pure races and may be supposed to give rise to reproductive cells of pure descent. This is the form in hybrids between closely related parents (monohybrids), and probably forms the basis for the regular reversion in them. The other type of mitosis is irregular. It is suggested that this kind of maturation mitosis may organize cells of mixed descent, and if found in hybrids from parents rather distantly related, would constitute the basis for such mixture of the characters of the pure parents as occurs in these hybrids. However, after

the characters have become mixed in all possible proportions, and the limit of variation thus reached, normal mitoses probably occur. Thus it appears that the mingling of the characters, as well as the regular reversion in hybrids, may have a morphological basis.

Professor **Dean,** first reviewed the history of the study of zoölogy, and then considered the present status of zoölogical investigation and teaching in that country. With the aid of lantern illustration, descriptions were given of the laboratories, the fauna available for study, and the prominent Japanese workers.

Professor **Osborn's** paper was presented by Dr. Hay. This has been published in full in *Science* for February 13, 1903.

M. A. Bigelow,
*Secretary.*

## SECTION OF GEOLOGY AND MINERALOGY.

February 16, 1903.

The section met at 8:15 P. M., Professor J. F. Kemp presiding. The minutes of the last meeting were read and approved. The following program was then offered:

**William Hallock,** An Ascent of Mt. Whitney, California, with Notes on the Geology.

**J. F. Kemp,** The Leucite Hills of Wyoming.

### Summary of Papers.

Professor **Hallock's** paper was as follows: Mt. Whitney with an altitude of 14,625 feet claims the distinction of being the highest peak in the United States. It is a mountain of high relief in a rugged country. The easiest way to the summit is by a five-day journey skirting the canyons from the southwest. Sedimentary rocks do not occur in the part of the Sierras near Mt. Whitney. The country rock is a deeply weathered granite, split by countless joint planes. Mt. Whitney exhibits the effects of glacial sculpturing, and adjacent to its top, holds many small lakes in the cirques, which have resulted from ice undercutting. Professor Hallock also described a lava flow

with cinder cones on Volcano Creek, Cal. Lantern slides were used to bring out these features and to illustrate the topography.

Professor **Kemp** said: Before giving an account of his work in this region with Professor Knight, of Wyoming University, he described the mineralogical and petrographical features of the leucite rocks as they occur in America, and referred to their discovery in Wyoming by the members of the Fortieth Parallel Survey. These rocks were originally determined by Dr. Zirkel. The speaker then called attention to Dr. Cross's more extended work in the district. His own contribution had to do with the general geology of the Leucite Hills. As many as seventeen separate mesas and buttes isolated by erosion have been mapped, representing in most cases single extrusive and intrusive flows of these rare rocks. They are found in sandstones near the top of the Cretaceous, and their distribution and field relations tend to confirm the view that they are volcanic outpourings at different times from a laccolithic reservoir of great extent, which is nowhere exposed at the surface. Lantern slides were used in illustrating the geology, and specimens of the rocks in question were exhibited.

George I. Finlay,
*Secretary, pro tem.*

## SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

February 23, 1903.

The regular meeting of the Section was held February 23, in conjunction with the New York branch of the American Psychological Association, Professor Thorndike presiding. Afternoon and evening sessions were held, the members dining together at the close of the afternoon session. The following papers were presented:

**E. W. Scripture,** Phonetic Surveys.

**Clark Wissler,** Correlations of Measurements of Growth. (Read by title.)

**J. H. Bair,** Correlations in School Children.

**J. E. Lough,** Apparent Motion in Stereoscopic Vision.

**Robert MacDougall,** An Experiment in Facial Vision.

**E. H. Sneath,** Notes on the Washington Meeting.

**J. McKeen Cattell,** Grades for Mental Traits.

**W. H. Davis,** A Preliminary Report on Tests of One Hundred Men of Science. (Read by title.)

## Summary of Papers.

Professor **Scripture's** paper was as follows: After brief mention of the phonetic surveys being carried on by Grierson in India and Guilleron in France, a description was given of the chief talking-machine methods that may be used for this purpose. It was pointed out that the advances in the construction of phonographs, graphophones and gramophones during the last couple of years have been so great as to revolutionize these methods. It was also explained that making a speech record was like taking a photograph; everybody can take a picture, but a good picture requires skill. By use of the graphophone the records made on wax cylinders can be used for making metal molds; from these indestructible molds copies in hard wax can be made. The gramophone method likewise furnishes metal molds from which hard discs are produced; but the talking machine requires an expert. This gramophone method was lately used on three expeditions sent out by the Vienna Academy of Sciences. The new methods furnish records that are perfect in recording every detail of the voice. There is not the slightest loss even of the most difficult consonants. Criticisms stating the contrary are derived from acquaintance with methods that are now out of date. From the gramophone records the curve of speech can be traced off with great accuracy; whereby every detail of the voice can be measured. A similar method can be applied to phonograph records. It was urged that the fast disappearing dialects and languages should be recorded and preserved in one of these ways. It was pointed out that such records could be made and delivered at smaller cost per word than in the case of Guilleron's "Atlas." It was stated that the various talking machine companies have shown self-sacrificing interest in such

work, and that the Victor Talking Machine Company would be willing to loan its record-talking car when it is finished. Exhibits of various material and speech curves were made.

Dr. **Bair** stated that the measurements were taken on Worcester school children. A high coefficient of correlation was shown between stature and height-sitting, stature and weight, and height-sitting and weight. Between stature, height-sitting, weight, with length of head and width of head the amount of correlation was much less and much more irregular than between the measurements first named. This irregularity was partly due to the small number of cases examined.

Professor **Lough** said that stereoscopic pictures may be united without the aid of a stereoscope, *i. e.*, by direct fixation, whenever the distances between similar objects in the two pictures is not greater than the interocular distance. When pictures are so united — giving a direct perception of the third dimension — any movement of the picture from side to side gives the impression that objects in the background are moving through a greater distance than are the objects in the foreground. This "slipping" of the background is perceived with still greater vividness when the picture remains stationary and the head is rotated or moved from side to side. In bringing a stereoscopic picture nearer the eyes the background seems to approach more rapidly than the foreground, and in moving the picture away from the eyes the background seems to move away more rapidly. The apparent motion in stereoscopic pictures seen under the above conditions is probably due to the fact that the angle of parallax remains constant, while the line of direction varies, with every movement of the head or of the picture.

The paper of Professor **MacDougall** supplements and in three respects aims to correct the reports of previous experiments on facial vision. In the perception of objects in proximity to the face independently of the sense of sight, the nature of the sensory impression upon which perception depends is not commonly discriminated. In the present investigation the percentage of correct perceptions was found to lie between 50 and 75, that is, within the subliminal region. This result is contrary to previous work

in which the percentage lay clearly above the threshold of 75. If a true perceptual process be involved, the percentage of correct responses should be a function of the absolute differences between the objects discriminated. This was found to be the case in the present set of experiments, but not in preceding investigations. In work published heretofore the perception was reported to be mediated solely by sensations of sound, but in the present investigation the shutting off of auditory stimulation made practically no reduction in the percentage of correct responses.

Professor **E. H. Sneath** said that the Washington meeting, if compared with a possible meeting of psychologists twenty-five years ago, shows the lines along which progress has been made. Such a comparison demonstrates clearly (1) the special training required of the psychologists of to-day; (2) the position of psychology among the sciences; (3) the growth of productive scholarship; (4) the differentiation of the work into experimental, genetic, comparative, abnormal, educational, etc.; (5) the development of new methods of approach.

The paper of Professor **Cattell** treated the accuracy with which grades can be assigned for college studies, and the methods to be employed in assigning grades. Those who do well in one study or have one trait in excess are likely to do well in other studies and to have other traits in excess, and they are more likely to succeed in after life. It was shown, however, that the grades assigned to students have not very great validity. It was recommended that grades be assigned in a scale of ten and that a probable error be attached to the grade. The grades should represent groups of equal size rather than equal differences in merit. The paper also discussed the grade assigned to large groups for mental, moral and physical traits, and gave some of the results that the writer had obtained.

James E. Lough,
*Secretary.*

## BUSINESS MEETING.

March 2, 1903.

The Academy met at 8.15 P. M., Vice-President Poor presiding. The minutes of the last business meeting were read and approved.

The Secretary reported from the Council as follows: that the Executive Committee of the Council, constituted a Committee on the Budget for 1903 presented the report, a copy of which is filed herewith, which was accepted by the Council; that a special committee of the Council had considered the advisability of depositing the library of the Academy in the American Museum of Natural History and had presented a report, a copy of which is filed herewith, favoring such transfer; the Council had adopted this report.

The following candidate for active membership, approved by the Council, was duly elected: Ralph W. Tower, American Museum of Natural History.

The following candidates for election as Fellows of the Academy, on recommendation of the Council, were unanimously elected:

Frederick J. E. Woodbridge, Columbia University.

Edward Phelps Allis, Jr., Mentone, France.

Adjourned.

## REPORT OF THE COMMITTEE ON THE BUDGET.

February 9, 1903.

The Executive Committee, constituted by vote of the Council on January 5th a Committee on the Budget, presents the following estimates for the year 1903:

| | |
|---|---|
| Estimated income | $3,000 |
| Cash on hand, December 15, 1902 | 3,756 |
| | $6.756 |

Estimated Expenses.

| | |
|---|---|
| Recording Secretary | $300 |
| Librarian | 200 |

| | |
|---|---|
| Treasurer | 50 |
| Dues, Scientific Alliance | 50 |
| Miscellaneous expenses | 150 |
| Publications in press | 600 |
| Publications for current year | 1,000 |
| | $2,350 |
| Estimated Surplus | $4,406 |

For the Committee,

HENRY E. CRAMPTON,
*Recording Secretary.*

## REPORT OF THE SPECIAL COMMITTEE ON EXCHANGES AND THE TRANSFER OF THE LIBRARY.

A second meeting of the Special Committee consisting of the Library and Publication Committees was held at the American Museum on January 12, 1903. Present: Professors Cattell, Britton, Boas, Bumpus, Farrand and Crampton. Originally constituted to consider the Academy's exchanges, this Committee, together with Professor Britton, was empowered to consider the question of transferring the Library to the American Museum.

As a result of its deliberations, the Committee recommends that the Library of the Academy be deposited in the American Museum of Natural History, the Library Committee retaining general control, and the matter of exchanges remaining with the Academy. The Museum will assume the custodianship of the Library, and the expense of cataloging and suitable book-plating; the Academy's books will be placed in the library of the Museum unless they should be duplicates of those already on the shelves, in which case they will be stored; the Museum will bind such books as it may desire, the cost of binding to be a lien upon the books so bound; the Museum will execute the transfer. The Museum can assume no liability for damages by fire. The Library will be open for consultation from 9 A. M.,

to 5 P. M. The above agreement may be terminated six months after due notice by either party.

With regard to the matter of exchanges, the Committee recommends that after the transfer of the Library, the Library Committee should collect information regarding the number of societies and of libraries which receive the Academy's publications; and that it should make systematic efforts to induce libraries to subscribe for such publications, offering back numbers as far as possible, with a view to reducing the number of societies receiving the Academy's publications by way of exchange. The Committee also recommends that all requests for the institution of exchanges be referred to the Library Committee with power.

HENRY E. CRAMPTON,
*Secretary.*

## SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

MARCH 2, 1903.

The section met at 8:30 P. M. Dr. Charles Lane Poor presiding. The minutes of the last meeting were read and approved. The following program was then offered:

**William Hallock,** MEASUREMENT OF THE ALTITUDE OF MT. WHITNEY, CALIFORNIA, BY BOILING POINT DETERMINATIONS.

**S. A. Mitchell,** THE DISCOVERY OF NEW GASES IN THE SUN.

### SUMMARY OF PAPERS.

Professor **Hallock's** paper was as follows:

At the time of the ascent of Mount Whitney last summer by the party under Mr. Harrington Putnam, apparatus was taken to the top, and a determination of the boiling point was made at ten o'clock on August 23. The observed boiling point was 186°.47. Applying the instrumental corrections and reducing this by the Smithsonian tables, the corresponding barometric pressure was 17.70 inches. The Weather Bureau kindly furnished the barometric pressure, temperature and vapor tension

for Independence, California, for that morning. They were: barometric pressure 25.93 inches, temperature 78°.0, vapor tension 0.110 feet. Substituting these values in the formula given by Bigelow on page 490 of the second volume of the annual report of the "Chief of the Weather Bureau" for 1898–1899, a difference in altitude between Independence and Mount Whitney of 10,633 feet results. Inasmuch as this determination was made five feet below the actual summit of the mountain, and Independence is 3,910 feet above sea-level, it would give a final value for the elevation of Mount Whitney of 14,548 feet. It may be stated in this connection that the value which was obtained by Secretary Langley as a result of a very complete series of determinations was 14,522 feet. The probable error in either case is undoubtedly not less than ten or fifteen feet. One object of this determination was to show the availability of boiling-point apparatus which is light and convenient for such determinations as being very much more reliable than the aneroid barometer, and much easier for transportation than the mercurial barometer.

In the course of Dr. **Mitchell's** paper it was shown that the interdependence of the sciences is nowhere better illustrated than in spectroscopic work, when astronomy, the most ancient of all the sciences, goes hand in hand with physics to find a new chemical element. In recent years, through spectroscopic researches several metals have been added to the list of elements. In April, 1895, by investigations on a specimen of clevite, Ramsay announced the discovery of terrestrial helium which gives a line in its spectrum agreeing with the $D_3$ line familiar for more than twenty-five years in stellar, prominence and chromospheric spectra. About the same time, Rayleigh and Ramsay announced the discovery of another new element which was called argon. In the early summer of 1898, Ramsay found two more gaseous elements, neon and krypton, and subsequently a heavier gas to which the name xenon was applied. These five new elements, helium, neon, argon, krypton and xenon are found in atmospheric air, and can be obtained from air by fractional distillation by making

use of the extremely low temperatures of liquid air and liquid hydrogen. Atomic weights have been assigned as follows: helium, 4; neon, 20; argon, 40; krypton, 82; and xenon, 128, and the gases seem to form a series in the periodic table of elements between the fluorine and sodium groups.

Investigations carried out on photographs of the "flash" spectrum at the Sumatra eclipse of 1901 enabled Dr. Mitchell to find that the remarkable variations in the intensities of the lines of the ordinary solar spectrum and of the "flash" spectrum (for one does not *look* to be the reversal of the other) are due to the different *heights* to which the vapors of the various metals ascend above the sun's surface. As a consequence, although helium lines are not found in the ordinary solar spectrum, the helium lines in the spectrum of the chromosphere are very bright indeed.

In view of the similarity of the new gases, neon, argon, etc., to helium, and as the helium lines are such prominent ones in eclipse spectra, it was expected that the new atmospheric gases — at least the lighter ones, neon and argon — might appear in the sun's atmosphere. A detailed comparison of the lines of the flash spectrum measured by Dr. Mitchell with those of the new gases lately published has led to the discovery that neon and argon are both probably present in the chromosphere, while it is doubtful whether krypton and xenon are there or not.

S. A. Mitchell,
*Secretary of Section.*

## SECTION OF BIOLOGY.

March 9, 1903.

The Section met at 8.15 P. M., Professor Bashford Dean presiding. The following papers were presented:

**W. S. Sutton,** Chromosomic Reduction in its Relation to Mendel's Law.

**Graham Lusk,** Influence of Nutrition on the Growth of Young Mammals.

**C. L. Bristol,** On the Colors and Color-Patterns of Certain Bermuda Fishes.

### Summary of Papers.

Mr. **W. S. Sutton** pointed out that the processes of synapsis and reduction in the germ-cells of the grasshopper *Brachystola* are such as to indicate strongly that they are the causes of the character-reduction which forms the basis of the Mendelian principle of heredity. Probably the reducing division in *Brachystola* does not effect a separation of chromosomes into maternal and paternal groups, but the chromosome-series of the mature germ-cells is made up of a chance combination of chromosomes from the two parents. This is in accord with the results of Mendel and others who have shown that hybrid offspring exhibit a chance combination of characters from the two parental lines.

Professor **Graham Lusk** based his paper upon experiments conducted in his laboratory by Dr. Margaret B. Wilson (*Amer. Jour. Phy.*, VIII., 197, 1902), whose results support his own earlier work. It was shown that new-born pigs develop normally when fed with skimmed cow's milk, or with the same milk to which three per cent. of dextrose or lactose has been added. The growth is proportional to the calorific value of the food — always supposing sufficient proteid to be present. This agrees with the results of other workers who have studied the growth of children and other young mammals. The growth of the pigs was on the average about 215 grams growth for 1,000 calories in the food. Eighteen to nineteen per cent. of the energy of the food was retained in the body as new tissue.

Professor **C. L. Bristol's** paper dealt with correlations between habits and appearance with reference to warning and protective coloration of these fishes. An abstract will soon appear in *Science* in the proceedings of the American Morphological Society.

M. A. Bigelow,
*Secretary.*

## SECTION OF GEOLOGY AND MINERALOGY.

March 16, 1903.

The Section met at 8.30 P. M., and, in the absence of Professor Kemp, Dr. Julien was made temporary chairman.

The following program was presented :

**A. W. Grabau,** The Geology of Becraft Mountain, New York.

**C. W. Dickson,** The Mineralogy and Geology of the Sudbury-Ontario-Copper-Nickel Deposits.

## Summary of Papers.

Dr. **Grabau** said that Becraft Mountain, in Columbia Co., N. Y., is an outlier of the Helderberg Mountains. Its base is formed by the upturned and eroded rocks of the Hudson Group, chiefly, the Normans Kill shales. Uncomformably upon this rests the upper part of the Manlius limestone, followed in turn by the members of the New York Devonian up to and including the Onondaga limestone. The structure of the eastern and southen portion of the mountain, which is of the Appalachian type was discussed, and the excessive folding and faulting upon it were illustrated by maps and sections. The paper was discussed by Dr. Stevenson and Dr. Julien.

In Mr. **Dickson's** paper it was shown that by magnetic concentration of the ore nearly all the nickel can be eliminated from the pyrrhotite, proving that the element is present in a separate mineral and that it does not replace part of the iron of the pyrrhotite isomorphously. The economic concentration of the nickel by magnetic methods is, however, practically impossible. The composition of the nickel mineral corresponds closely to that of pentlandite, but there is always an excess of (FeNi) over that required by the formula (FeNi)S in the proportion 11 : 10.

After studying the relations of the ore and rock minerals in the field and by the aid of the microscope, the conclusion was reached that, in their present form, the deposits are replacements along crushed zones through which the mineral-bearing waters circulated, and that they cannot be original magmatic segregations, as generally held.

George I. Finlay,
*Sectretary, pro tem.*

## SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

March 23, 1903.

The regular meeting of the Section was held at 8.30 P. M., Professor Thorndike presiding. The following program was offered:

**Clark Wissler,** Observations on Abnormalities of the Hard Palate.

**A. Hrdlicka,** Physical Anthropology of the Hyde Expedition in 1902.

Summary of Papers.

Dr. **Clark Wissler's** paper reported progress in the measurements of the casts of the hard palates of idiots. The first thing to be considered in this work was the determination of the significant points and dimensions in the palate. The results presented indicated important structural relations between the width at the canine teeth and the length of the palate measured from the first molars and the maximum height of the arch. The comparative study of the palates of normal and of idiotic persons will be based upon these measurements.

During 1902 Dr. **Hrdlicka** made two expeditions, one of seven and the other of three months' duration, to the southwestern United States and Mexico. These expeditions were the conclusive ones of a series of five, begun in 1898, made for the purpose of ascertaining the physical characteristics of all those present as well as extinct tribes which occupy or occupied the region marked by the boundaries of the ancient Pueblos, Cliff-Dwellers and Nahaun (Toltec, Chichimec, Aztec) peoples. The region thus bounded extends uninterruptedly from Utah and Colorado to the Mexican States of Morelos and Guerrero, and in it live at present a little over forty tribes or distinct groups of Indians. About nine tenths of all these peoples were visited on the five expeditions and examined; all the measurements and data secured are being studied, but to arrive at detailed results will require several years.

What can now be safely stated is: (1) All the ancient as well as the modern peoples in the region mentioned belong to

three physical types, and these types are identical with those widely represented in all directions outside of this region; and (2) a very large majority of the present peoples examined are physically identical with the prehistoric inhabitants of these same districts (so far as could be ascertained from the osteological material recovered); the prehistoric remains (osteological) show no type that is not represented somewhere in the region covered to-day and there is no type among the living tribes not represented among the ancient ones.

The visit of so large a number of tribes, as well as the search for skeletal remnants of the extinct peoples, afforded a very good opportunity for general ethnological and archeological observations, the substance of which can be stated as follows: The Mexican Indians visited, with the exception of the Huichols and Tarahumares, are in their mode of life and habits far more like the whites about them than is the case with our Indians of the southwest; nevertheless, the Mexican tribes preserve much that would be of value to the ethnologist. Dr. Hrdlicka's exploration in northern Jalisco and in Zacatecas resulted in the discovery of the ruins of eleven good-sized pueblos or towns, the excavations at one of which showed that its inhabitants had reached a comparatively high grade of culture. The pueblo and cliff ruins of our southwest may be compared to a head which connects by a long narrow neck running through Cora Grande in Arizona, Coras Grande in Mexico, Zape in Mexico and La Quemada in Zacatecas, with a large body of ruins which begin in southern Zacatecas and Jalisco and extend through all the southern part of Mexico to Guatemala and Central America. La Quemada was found to be above all a fort, in all probability the most representative stone-built native fort in North America.

In Zacatecas Dr. Hrdlicka discovered a colony of Tlascaltecs, transplanted hither by the Spaniards in the seventeenth and eighteenth centuries; and further south he found two villages still occupied by the remnants of the ancient Chichimecs of Teul. South of Juchipilla, in Zacatecas, is located a perfect cliff-dwelling, probable the most southern one in existence. This particular ruin, known under the name of "Las Ventanas"

(the windows), has been visited by at least one American before, namely, by Miss Britton.

JAMES E. LOUGH,
*Secretary.*

## BUSINESS MEETING.

APRIL 6, 1903.

The Academy met at 8.15 P. M., Vice-President Poor presiding. The minutes of the last business meeting were read and approved.

No report from the Council was presented.

There being no business to come before the meeting the Academy adjourned.

HENRY E. CRAMPTON,
*Recording Secretary.*

## SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

APRIL 6, 1903.

Section met at 8:20 P. M., Vice-President Poor presiding. The minutes of the last meeting were read and approved.

Mr. **P. H. Dudley,** C.E., Ph.D., of the New York Central and Hudson River Railroad, read a paper full of interest to those familiar with American railroad methods, on "STREMMATOGRAPH TESTS: PRINCIPLES AND FACTS RELATING TO THE DISTRIBUTION OF THE STRAINS IN THE BASE OF RAILS UNDER MOVING TRAINS." This paper is published in full in *Science,* N. S., Vol. XVII, No. 436, May 8, 1903.

S. A. MITCHELL,
*Secretary.*

## SECTION OF BIOLOGY.

APRIL 13, 1903.

The Section met at 8:30 P. M., Professor Bashford Dean presiding. After reading the minutes, the following program was presented:

**A. G. Mayer,** The Instincts of Lepidoptera.

**H. E. Crampton,** Variation and Reproductive Selection in Saturnid Moths.

Summary of Papers.

Dr. **Mayer's** paper was a mere preliminary account of certain observations made by the writer. It is planned that the research will be continued and finally published conjointly with Miss Caroline G. Soule. Certain lepidopterous larvæ, such as *Danais plexippus*, are negatively geotactic and positively phototactic toward the ultra-violet rays. The combination of these reactions in nature maintains the larva at or near the top of its food plant, where incidentally it finds the youngest and best leaves, and tends to prevent its crawling down and away from the plant, thus incurring risk of starvation. Other larvæ, such as *Pyrrharctia isabella*, are indifferent either to the attraction of gravitation or to ordinary variation in conditions of light. Others react differently at different stages of development. Larvæ which will devour only certain definite species of leaves may be induced to eat sparingly of any other sort, provided the instinct to eat be first set into operation by the presence of the proper food plant. Under such conditions about the same number of bites are taken upon each presentation of the uneatable food to the larva. This phenomenon may be called "momentum of the reaction" and inclines one to conclude that the eating reaction is probably an unconscious reflex. Another series of experiments appeared to show that larvæ are unable to learn to follow a definite path to their food, and that the associative memory of lepidopterous larvæ does not endure for as long a time as ninety seconds. Certain larvæ when about to pupate display a well-marked geotropism.

The mating instinct is called into play by the perception of the characteristic odor of the female, and is merely a phenomenon of chemotaxis uncomplicated by æsthetic appreciation or sexual selection on the part of the female.

Professor **Crampton** described briefly the principal results of a statistical study of the correlation between structural character-

istics and reproductive ability or disability in *Samia cecropia*. It was shown that the pupæ of those individuals, male and female, which mated were different from those which failed to mate, although all were placed under the same conditions as far as possible. True reproductive selection was evident, and related to typical conditions as well as to variabilities. A brief discussion was given of the real basis for the selective process and of the relation between reproductive selection manifested after emergence to that selection which occurred during pupal existence.

M. A. BIGELOW,
*Secretary*.

## SECTION OF GEOLOGY AND MINERALOGY.

APRIL 20, 1903.

Section met at 8.15 P. M., Professor James F. Kemp presiding. The minutes of the last meeting of section were read and approved.

The following program was then offered:

**A. A. Julien,** THE HORNBLENDE SCHIST OF SPUYTEN DUYVIL CREEK, MANHATTAN ISLAND.

**D. W. Johnson,** THE GEOLOGY OF THE CERILLOS HILLS NEW MEXICO.

SUMMARY OF PAPERS.

Dr. **A. A. Julien,** in the first paper of the evening, presented the results of his work on the hornblendic schist which occurs at the extreme northern end of Manhattan Island, near Spuyten Duyvil Creek. He was able in the first place to prove the undoubted igneous origin of this rock by the unaltered crystals which it still preserves and which point to an original gabbro. The speaker then presented his views in favor of the igneous origin of all the hornblende schists of Manhattan Island.

Mr. **D. W. Johnson** presented a paper on the "Geology of the Cerrillos Hills, New Mexico." The Cerrillos Hills form the most northerly group of a series of four laccolithic mountain masses in northern central New Mexico. The rela-

tion of these hills to the associated Cretaceous beds, and the age of the intrusions were discussed. A brief petrographical description of the several igneous rocks was given, and the subdivision and correlation of the sedimentaries on palæontological grounds considered. The origin of the anthracite coal of the Madrid area, and the origin of the famous turquoise deposits of the hills were then discussed. The speaker closed with a résumé of the geological history of the region. An interesting discussion followed.

George I. Finlay,
*Secretary, pro tem.*

## SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

April 27, 1903.

The regular meeting of the Section was held in conjunction with the New York branch of the American Psychological Association, Professor Thorndike presiding.

The following papers were presented:

**E. L. Thorndike,** Mental Traits in the Two Sexes.

**W. H. Davis,** A Preliminary Report of Tests of Scientific Men.

**S. C. Parker,** Correlation of School Abilities.

**Robert MacDougall,** The Specialization of the Hand in Relation to Mental Development.

### Summary of Papers.

Professor **E. L. Thorndike** reported the results of extended measurements of mental traits in the two sexes. In general the females were less variable. In the case of children 9 to 12 the ratio of female to male variability was .92; in the case of children 13 and 14 it was 1.02; in the case of children 15 it was .97; in high school pupils .95; in college students .85. In the abilities measured the greatest difference found was the female superiority in the tests of impressibility, such as the rate and accuracy of perception, verbal memory and spelling. In these only about one third of the boys reach the median mark for girls.

Mr. **William Harper Davis's** paper dealt with some twenty physical and mental measurements made upon one hundred professional men of science, under the auspices of the Committee on Anthropology of the American Association for the Advancement of Science. No significant correlations were found between any of the tests and the several departments of scientific activity, although the cases were too few to warrant an expectation of decided results. (The superiority of psychologists in "logical memory" was attributed to the accident that the passage used in the tests was psychological in content.) Vivid mental imagery was less common among the older than among the younger men. Two cases of color-blindness were detected.

Comparison with Columbia College students, upon whom the same measurements have been made, revealed no significant difference between the two groups, except such as would naturally arise from their disparity in age.

Critical comments were made on some of the tests and on the method of administering them. It is expected that these measurements will be continued under the direction of Professor J. McK. Cattell, who is engaged upon a comparative study of scientific men.

Mr. **S. C. Parker** presented a paper upon "Correlation of School Abilities." Several investigations in Teachers College have had for their subject "The Correlation of School Marks." The method and results of these researches are set forth in Vol. XI, No. 2, of the "Columbia University Contributions to Philosophy, Psychology and Education." This paper reports the results of some new calculations based on the marks of 245 boys in a New York City high school.

It must be borne in mind that we do not know exactly what school marks represent; they may represent real ability in the school subjects or merely the ability to get marks.

In performing the statistical work, it is important to transmute each teacher's marks separately. This point is mentioned because the neglect of it by one investigator lays his results open to question.

There is not any very great variation in the correlations between marks in academic subjects, such as the languages, sciences and mathematics. The Pearson coefficients run between 40 per cent. and 60 per cent. The correlations of drawing with academic subjects are low — lying as a rule between 0 and 25 per cent. From a psychological standpoint, the academic correlations are high. But it must be borne in mind that many constant errors enter which would make the correlations much higher than the essential relationships would be. From an educational standpoint the correlations are low. They show the futility of the belief in general brightness for all things, and are one of the best arguments for the elective system.

James E. Lough,
*Secretary.*

## BUSINESS MEETING.

May 4, 1903.

The Academy met at 8.15 P. M., Vice-President Poor presiding. In the absence of the Recording Secretary, the reading of the minutes of the last meeting was dispensed with.

No business was reported from the Council. As no new business was presented, the Academy adjourned.

Charles Lane Poor,
*Secretary, pro tem.*

## SECTION OF ASTRONOMY, PHYSICS, AND CHEMISTY.

May 4, 1903.

The Section met at 8.30 P. M., Vice-President Poor presiding. The minutes of the preceding meeting were read and approved.

The following papers were presented and read :

**Ernest R. von Nardroff**, A New Interferometer Method for Measuring the Refractive Index of a Transparent Plate.

**G. B. Warring**, Some Peculiarities of the Gyroscope.

## Summary of Papers.

Mr. **von Nardroff** stated that this method was planned to avoid the use of compensation, which leads to grave errors unless in the compensating material the ratio of the velocities for any two wave-lengths is the same as in the substance being measured. It is frequently impracticable to fulfil this condition, as for example by using as a compensator a second plate of the same material. Air compensation is of course out of the question.

In the present method, in which no use is made of white light fringes, the transparent plate, a microscope cover-glass, for instance, is mounted on a special stage perpendicular to the path of one of the beams in a Michelson interferometer. With sodium light, bands are seen that are generally distorted through lack of perfect parallelism between the surfaces of the plate. The stage is now rotated forward about a vertical axis through an angle of 45° up to a fixed stop, thus increasing the path through the plate. Slowly turning the stage backward, the bands passing a fixed point in the field are carefully counted until the plate returns to the perpendicular position, when the motion of the bands reverses. A new count is now made while the stage is turned past the perpendicular, backward 45 degrees to a second fixed stop. Generally these counts differ by a few tenths of a band, owing to imperfect mounting of the stage as a whole on the interferometer, but they may be averaged without sensible error. Since the light passes through the plate twice, one half the number of bands counted should be taken to represent the increase of optical path, $N$, in wave-lengths. The thickness, $t$, of the plate at the part of it observed in the interferometer may be measured by means of a micrometer caliper or by a spherometer. The following exact formula, much simplified through the use of precisely 45 degrees of rotation, gives the value of the refractive index, $\mu$:

$$\mu = \frac{\frac{1}{2} + \left(1 - \sqrt{\frac{1}{2} - \frac{N\lambda}{t}}\right)^2}{2\left(1 - \sqrt{\frac{1}{2} - \frac{N\lambda}{t}}\right)}.$$

For sodium light where the wave-length, $\lambda$, is 0.0005893 mm.,

$$\mu_{na} = \frac{0.5 + \left(0.2929 - \frac{0.0005893N}{t}\right)^2}{2\left(0.2929 - \frac{0.0005893N}{t}\right)}.$$

This method has been extended to the measurement of doubly refracting plates, such as mica. The plate crystalline must contain in its plane at least one of the axes of the so-called ellipsoid of elasticity, and must be mounted with this axis vertical. The bands may be observed through a Nicol prism having its shorter diagonal vertical.

Dr. **G. B. Warring** detailed the results of some interesting experiments with the gyroscope. The paper led to an interesting discussion.

S. A. MITCHELL,
*Secretary.*

## SECTION OF BIOLOGY.

MAY 11, 1903.

A regular monthly meeting was held at the American Museum of Natural History on May 11, Professor Bashford Dean presiding.

The following papers were presented and read :

**H. F. Osborn,** ON RECENT MODELS AND RESTORATIONS OF A NUMBER OF EXTINCT ANIMALS, WITH A DISCUSSION OF THEIR PROBABLE HABITS AND MODES OF LIFE.

**E. L. Thorndike,** NATURAL SELECTION AND FERTILITY IN MAN.

**C. T. Brues,** THE INTERNAL FACTORS OF REGENERATION AND REVERSAL OF ASYMMETRY IN THE CRUSTACEAN ALPHEUS.

### SUMMARY OF PAPERS.

Professor **Osborn's** paper was based upon models and restorations from the Department of Vertebrate Paleontology of the American Museum of Natural History, prepared by Charles

Knight under the direction of the speaker with the assistance of other members of the department. Numerous models and drawings were exhibited and described. Of special interest were the following: *Elephas imperiales* (Imperial mammoth); *Trilophodon productus* (Miocene mastodon); and *Icthyasaurus* and young; several Pleistocene rhinoceroses; and *Diplodocus* (a bird-catching dinosaur).

Professor **Thorndike** reported a study of the size of families of college graduates during the nineteenth century and of the descendants of a New England family during the eigthteenth and nineteenth centuries. The average number of children in the latter case rose gradually to an acme in the generation born about 1720 and then fell steadily, the figures for eight generations being 5.3, 6.3, 7.7, 10.0, 7.2, 5.5, 4.4, 3.8. This rise is inconsistent with the common hypothesis that social custom is the cause of change in the productivity of races. So also is the form of the surface of frequency of family size in the later decades of the nineteenth century (see *Popular Science Monthly*, May, 1903, p. 68). A real decrease in natural fertility would account perfectly for the statistical appearances found; and, if we judge only by them, is the most likely hypothesis.

Mr. **Brues** presented a preliminary account of "The internal factors of Regeneration and Reversal of Asymmetry in the crustacean *Alpheus*." Przibram and Wilson have recently shown that when the larger of the asymmetrical chelæ of these animals is amputated, the smaller one on the opposite side develops into a claw of the large type while a small one regenerates on the stump of the large one. If the nerve of the small claw be severed at the time of removing the large one, reversal does not take place, or only incompletely. Histological examination of animals in which such changes are taking place indicates that the regeneration and remodeling are influenced by the nervous system, due possibly to increased nutrition in the ganglion which supplies the small chela. As the nervous system shows no morphological asymmetry corresponding to that of the claws, it propably acts only in a passive way in determining the type of the claw, although it evidently gives the

stimuli for the more minute changes which take place in the remodeling of a small chela to form one of the large type.

M. A. Bigelow,
*Secretary.*

## SECTION OF GEOLOGY AND MINERALOGY.

May 18, 1903.

Section met at 8:15 P. M., Professor James F. Kemp presiding.

The minutes of the last meeting of section were read and approved.

The following program was then offered :

**George I. Finlay,** The Geology of the Nephelite Syenite Area at San José, Tamaulipas, Mexico.

**Fred H. Moffet,** The Copper Mines of Cobre, Santiago de Cuba.

Summary of Papers.

In his paper Dr. **Finlay** said in part : The town of San José in the State of Tamaulipas, Mexico, lies in a hollow surrounded on all sides by mountains, and is about seventy miles from the coast of the Gulf of Mexico. The range of peaks immediately to the south of it, and extending for fifteen miles in that direction, is of nephelite-syenite. The range is known as the San Carlos Mountains. San José itself is on the site of an eroded laccolith of andesite (locally known as "porphyry"), intruded into limestone. Some limestone masses stand on end within the area of the laccolith, and are thought to have floated or worked their way down to their present position during the intrusion of the igneous rock. There are two or three hundred of these isolated limestone masses, and it is in connection with these that the copper ores are found. Contact metamorphism has not been developed to any great extent in the limestone surrounding the laccolith, but has been greatly induced in the included masses ; marble, grossularite, vesuvianite and other minerals having been produced. Aside from the occurrence of the nephelite-syenite in the area south of the laccolith, the region is interesting on account of the dyke rocks which are found cut-

ting the andesite of the laccolith. Among these are found analcite-tinguaites and camptonites, as well as vogesite and diabase. Two main streams now drain the hollow formed by the down-cutting of the dome where the weaker andesite has been laid bare as far as the limestone cover has been cut back.

Dr. Finlay's paper was discussed by Professor Kemp, who called attention to the interesting association of types presented by the intruded rocks; and by Dr. H. S. Washington, who dwelt on the importance attaching to the additional localities here and elsewhere recently reported for the peculiar dyke rocks mentioned.

In his paper Mr. **Moffet** said in brief: The copper mines of El Cobre are located about nine miles west of the bay of Santiago, where a series of eruptive flows, andesites and rhyolites, are interbedded with fragmental rocks, agglomerates, breccias and tufts. The strike of the beds is east and west, and they dip at a low angle to the north. The series is cut by trap dykes and by two major systems of faults, the older of which runs east and west and carries with it the large ore bodies. The second major system has a direction nearly north and south. Cross faults cut and displace the ore bodies of the older system, and carry copper, though in less amount. The copper workings of the old English mining companies produced enormous quantities of very rich oxidized ore which gave place in the lower levels to sulphides. Much difficulty is encountered in handling the mine water on account of the porous nature of the country rock. At the present time the iron ore of the region is of much greater commercial importance than the copper.

In the discussion which followed, Professor Kemp spoke of the great importance to the United States which the iron ore deposits possessed on account of their great extent and convenient location. The ore is extremely low in phosphorus, but contains some sulphur. The copper may again be of great importance, strong efforts are being made at present for its exploitation.

E. O. Hovey,
*Secretary.*

## BUSINESS MEETING.

October 5, 1903.

The Academy met at 8:15 P. M., President Cattell presiding. The minutes of the last business meeting were read and approved.

The Secretary reported from the Council as follows:

That a communication had been received from the Secretary of the Scientific Alliance stating that an appropriation in aid of scientific research not to exceed $450 had been made from the income of the Herrman Fund, and that a grant of $50 in aid of research in zoölogy or botany had been made from the John Strong Newberry Fund. The Secretary stated that applications for grants should be sent to the Secretary of the society of which the applicant is a member, to be approved by the Council of that society before being forwarded to the Scientific Alliance.

The following candidates for active membership, approved by the Council, were duly elected: Dr. John Cutler Torrey, Dr. William Morton Wheeler, Dr. Joseph Hyde Pratt.

On the recommendation of the Council, Dr. William Morton Wheeler was duly elected a Fellow of the Academy.

The Academy then adjourned.

Henry E. Crampton,
*Recording Secretary.*

## SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

October 5, 1903.

The Section met at 8:30 P. M., Dr. Charles Lane Poor presiding. After the reading of the minutes the following papers were presented:

**Harold Jacoby and S. Alfred Mitchell,** A Combined Prismatic Transit and Zenith Telescope.

**George F. Kunz and Charles Baskerville,** Notes on Radium.

### Summary of Papers.

Professor **Harold Jacoby** and Dr. **S. Alfred Mitchell** exhibited a combined prismatic transit and zenith telescope. This instrument, just received by the Department of Astronomy of Columbia University, was made by Bamberg, of Berlin. It includes all the latest observational devices, including an eye-piece of the Repsold pattern for the automatic registration of transit observations.

Dr. **George F. Kunz** and Dr. **Charles Baskerville** gave an exhibition of radium of 300,000 activity, with some notes on the action of the Röntgen ray, ultra-violet light and radium on mineralogical substances. This paper has been published in *Science*, N. S., Vol. XVIII, 1903, pp. 769–783.

S. A. Mitchell,
*Secretary of Section.*

## SECTION OF BIOLOGY.

### October 12, 1903.

The first meeting of the academic year was held at the American Museum of Natural History on October 12, Professor Wilson acting as temporary chairman. As in former years, this first meeting after the long vacation was devoted to reports on scientific work carried on by members of the Section during the summer. The following notes indicate the lines of the work of the members who reported.

Professor **Bristol** in association with Professor **Mark,** of Harvard, directed the summer work of the Bermuda Biological Station Dr. **Hay** was very successful in collecting in Wyoming materials for his studies of fossil turtles. Professor **Osborn** directed explorations in Wyoming, Nebraska and South Dakota in the interest of the American Museum of Natural History, securing much valuable material which supplements collections previously made. Professor **Grabau** collected in Michigan materials for continuation of his studies on Devonian faunas. Dr. **Summer** directed the Biological Laboratory of the

United States Fish Commission at Woods Hole, Mass. Professor **Calkins** studied the relation of Protozoa to cancer and smallpox. Professor **Crampton** continued the accumulation of data relating to selection in Lepidoptera. Mr. **Bigelow** studied the early embryology of some crustaceans. Mr. **Yatsu** experimented on regulation and organization of nemertean eggs. Professor **Wilson** at Naples studied problems of localization and mosaic development of molluscan eggs.

M. A. BIGELOW,
*Secretary.*

## SECTION OF GEOLOGY AND MINERALOGY.

OCTOBER 19, 1903.

Section met at 8:15 P. M., Professor James F. Kemp presiding. There were no minutes to be read. Notice of the election of officers of the Section at the November meeting was read.

The following program was then offered:

**G. F. Kunz,** BISMUTH (NATIVE) AND BISMITE FROM SAN BERNARDINO CO., CAL. (Read by title.)

**G. F. Kunz,** CALIFORNITE (VESUVIANITE); A NEW ORNAMENTAL STONE. (Read by title.)

**E. O. Hovey,** OBSERVATIONS ON THE 1902–1903 ERUPTIONS MT. PELÉ, MARTINIQUE.

### SUMMARY OF PAPERS.

The main paper of the evening consisted of a lecture by Mr. **Hovey** on the principal events in the volcanic history of the island of Martinque during the last year and a half. He described the phenomena of the eruptions, the mud-torrents and mud-flows, the attendant and subsequent aqueous erosion on the slopes of the mountain, the rise and vicissitudes of the new cone of eruption and its wonderful spine or obelisk. The lecture was illustrated with about 95 lantern slides from negatives taken by the author on the two expeditions which he has made

to Martinique for the American Museum of Natural History since the eruptions began. The details of these observations are given in the publications of the Museum and in the *American Journal of Science*, the *Scientific American Supplement*, the *National Geographic Magazine* and elsewhere, and will not be repeated here.

The papers by Dr. **Kunz** have been published in full in the *American Journal of Science*, Vol. XVI, December, 1903, pp. 397, 398.

Three hundred fifty-two members and their friends were present.

EDMUND OTIS HOVEY,
*Secretary.*

## SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

OCTOBER 20, 1903.

The regular meeting of the section was held October 20, in New Haven, Conn., in conjunction with the New York Branch of the American Psychological Association and the Philosophical Club of Yale University.

The following papers were presented:

**S. I. Franz,** LOCALIZATION OF BRAIN FUNCTION.

**Robert Yerkes,** THE APPLICATION OF THE CONCEPT OF VARIABILITY IN REACTION-TIME WORK.

**W. P. Montague,** THE "SPECIOUS PRESENT" AND THE REAL PRESENT.

**E. H. Cameron** and **W. M. Steele,** THE EFFECTS OF PRACTICE ON THE POGGENDORFF ILLUSION.

**Charles H. Judd,** THE ZÖLLNER FIGURE.

**J. McKeen Cattell,** STATISTICS OF AMERICAN PSYCHOLOGISTS.

**Raymond Dodge,** THE PARTICIPATION OF THE EYE MOVEMENTS IN THE VISUAL PERCEPTION OF MOTION.

**Geo. T. Stevens,** ON THE HOROPTER.

**R. S. Woodworth,** INTELLIGENCE AND MOVEMENT.

**Lightner Witmer,** THE MINIMAL VALUE OF THE PSYCHOPHYSICAL REACTION-TIME. Read by title.

**H. R. Marshall,** Primary and Secondary Presentations. Read by title.

Summary of Papers.

Dr. **Franz,** of Dartmouth Medical College, presented an account of an attempt to determine by physiological experiments whether or not the so-called motor areas are also sensory in function. Cats were used in the investigation, and the results indicate that in these animals the motor cortex has also certain sensory functions. It was not determined with what sensory processes the areas are concerned, but results of clinical observations made it appear probable that the center for muscle sense is there located.

Dr. **Yerkes,** of Harvard University, stated that inasmuch as the degree of constancy of reaction-times differs for different species, individuals, conditions of the individual, modes and intensities of stimulation, it is clear that variability is an important quantity in the analysis of reactions, which should make possible the quantitative estimation of the influence of the various factors which play a part in determining the time of reaction.

The mean or average variability is generally determined in recent studies of reaction time, but of far more importance for comparative work is what may be known as the relative variability. This quantity is an index of the variability, which gives not the absolute variableness of the reaction time, but the ratio of the variability to the time of reaction. For reaction times, which are symmetrically distributed about a mode, the relative variability may be gotten from the formula

$$\frac{\text{mean variability} \times 100}{\text{mean}}.$$

In case of asymmetrical distribution Pearson's formula for obtaining the coefficient of variability should be used.

Examination of reaction time statistics in which the variability is given indicates that the relative variability, as well as the time of reaction and the mean variability, decreases with increase in the strength of the stimulus. For electric stimulation this appears to be true from the threshold intensity to that which

causes a reflex reaction, but in case of other modes of stimulation it is possible that beyond a certain point increase in intensity of the stimulus causes slower and more variable reactions.

Since the time of reaction varies with the intensity of the stimulus it is useless to compare reaction times for different modes of stimulation, or those of different species or individuals, unless the relative variability is known. It is not improbable that careful investigation of the relation of relative variablity to reaction time will furnish a satisfactory basis for the accurate comparison of different results. To say that one person reacts more quickly than another to a given stimulus without taking into account the variability of the reaction time is meaningless.

Dr. **Montague** said that a psychosis, like all systems, possesses in its totality a form or structure which is distinguishable, as the perceiving subject, from its individual contents, as perceived objects. Changes in the individual contents produce concomitant, though generally lesser, changes in the totality. The segment of duration or change perceived in any one moment is not itself a real change, but simply the *ratio of the change-rate of the individual contents to the change-rate of the totality, at that moment*; and this ratio, though finite and variable, does not itself require a finite time for its realization. Each unextended moment of "real" time is thus adequate for the appreciation of an extended period of perceptual or "specious" time.

The paper of Messrs. **Cameron** and **Steele** reported the results of a series of experiments dealing with the effect of practice on the Poggendorff illusion. (1) Quantitative determinations were made with a number of illusions; (2) practice with one illusion was carried on for an extended period; (3) determinations were again made with all of the illusions which were used before the practice series.

The apparatus used was demonstrated. The results show that the illusion tends to disappear after a period of seven weeks' practice. The effects of such practice were found to hold good for figure other than that which the practice was made.

The paper of Dr. **Judd** reported a series of quantitative determinations of the amount of illusion in the Zöllner figure

when the figure was rotated through 360 degrees and was divided so that the illusion for each of the long lines was determined without reference to the next long line. It was found that the illusion is not the result of equal deflections in opposite directions of the neighboring lines. In some cases one of two neighboring lines is not deflected at all, or even in a direction opposite to that usually assumed. The important deflection is in every second long line. Rotation through various angles shows that there are four positions in which deflection is great, four in which it is small.

Professor **Cattell** described the methods he has employed to select 1,000 American men of science for scientific study. Among about 4,000 scientific men, there are about 200 psychologists. The methods by which they were arranged in the order of merit were explained, and the possibility of measuring degrees of scientific merit by the positions and probable errors was discussed. Some statistics were then given in regard to the academic origin, course and distribution of the psychologists. They were educated at 76 different colleges, this large dispersal indicating that in general psychologists are not greatly influenced by the institutions at which they study. The members who pursued graduate studies at different institutions were: Berlin, Leipzig 35, Columbia 31, Clark 31, Harvard 30, Cornell 25, Yale 16, Johns Hopkins 13. Of the 200 psychologists, all but eight are engaged in teaching or administrative educational work, being distributed among 77 institutions. Statistics were also given in regard to publications, from which it appears that the United States contributes about one seventh of the more important publications, leading in experimental psychology. The paper will be published in the *American Journal of Psychology*.

Professor **Dodge** showed that photographic registration of eye movements has exposed the poverty and inaccuracy of all introspective data with respect to their number, velocity and amplitude, while it shows that, even if our consciousness were full and exact in all three aspects, it would be either useless or misleading as a datum in the visual perception of motion.

Every pursuit movement of the eyes is a definite muscular reaction to retinal stimulation. As such it is evidently conditioned both in direction and in velocity by some definite characteristics of the stimulus which occasions it. Since its accuracy can never transcend the accuracy of the data on which it occurs, it follows that the kinesthetic factor from a reactive pursuit movement could never correct nor materially augment the data furnished by the stimulus.

Moreover, the reaction of the eye involves a long reaction interval, about 160–170. This suggests both the relative importance of the actual motor response and a considerable elaboration of the sensory data in what seems like a simple reaction. But any reaction interval at all renders it impossible for the actual eye movement to parallel the movement of the object of interest either in velocity or in amplitude.

Experimental verification of the above takes two forms: Whenever all other sensory data for the perception of motion are suppressed, except the hypothetical kinesthetic factor, there is no immediate perception of motion. And whenever the former are distorted by eye movements, the appearance of motion is respectively decreased or increased, entirely without correction by kinesthetic data.

A horopter, said Mr. **Stevens,** will be formed when the two eyes are so adjusted as to enable the image of the point fixed to be located exactly at the maculas of the two retinas. It follows that horopters succeed each other in endless variety and with amazing rapidity. With every glance a new horopter is developed. Two tenets constitute the essential foundation for the doctrine of the horopter, the theory of actually horizontal and actually vertical meridians of the retinas and a doctrine of corresponding points.

Corresponding points of the two retinas are those which answer to proportional degrees of rotation of the eyes about the center of rotation, and which, from given individual points in the plane of fixation, each receive incident rays which must pass through the nodal points. They represent, therefore, the relation between the muscular and the retinal senses.

Dr. **Woodworth**, in his paper, argued that the mental cue of a voluntary movement was not ordinarily a kinesthetic image of the movement. Even in learning a new movement, experiment shows that no such image need be present. Since voluntary movement is developed from instinctive, the original mental cue must have been that provided by instinct, and the instinctive cue is never an image of the movement about to be made. The actual sensation of a movement can evidently not be the stimulus to that same movement, and the reproduced sensation can hardly have a motor power not possessed by the sensation itself.

JAMES E. LOUGH,
*Secretary.*

## BUSINESS MEETING.

NOVEMBER 2, 1903.

The Academy met at 8:15 P. M., Vice-President Poor presiding. The minutes of the last business meeting were read and approved.

There being no further business to come before the meeting, the Academy adjourned.

H. E. CRAMPTON,
*Recording Secretary.*

## SECTION OF ASTRONOMY, PHYSICS AND CHEMISTRY.

NOVEMBER 2, 1903.

The section met at 8.30 P. M., Dr. Charles Lane Poor presiding.

After reading the minutes the following papers were presented.

**Bergen Davis**, THE ELECTRICAL CONDUCTIVITY AND ABSORPTION OF ENERGY IN THE ELECTRODELESS DISCHARGE.

**Charles Lane Poor**, THE MEASUREMENT OF RACING YACHTS.

SUMMARY OF PAPERS.

Dr. **Davis** discussed the discharge produced in an annular vessel by the high frequency discharge from a Leyden jar sys-

tem. The vessel in which the discharge was produced contained electrodes which were connected through a galvanometer to a source of E.M.F. of 220 volts. When the discharge passed in the vessel, the gas became a good conductor. The conductivity as indicated by the galvanometer was found to depend on the pressure of the gas somewhat. That is, when the pressure becomes so low that the white discharge appeared, the conductivity increased to near a maximum. It remained nearly constant until at a low pressure the discharge disappeared, when the conductivity became zero.

The absorption of energy was measured by placing a hot-wire galvanometer in the circuit leading from the jars to the coil surrounding the vessel. The oscillating current passing through this galvanometer and coil can be expressed by

$$c = Ae^{-qt} \cos pt.$$

The greater part of the energy is dissipated in heating the gas and the vessel. The energy will be proportional to the square of the current, while the galvanometer reads current direct. Hence

$$\text{Reading} \propto \int_0^\infty e^{-2qt} \cos pt dt.$$

$$\text{Readings} \propto \frac{2p^2 + 3q^2}{4q(p^2 + q^2)},$$

$$\text{Readings} \propto \frac{1}{q}.$$

That is: a certain reading is obtained without the vessel in the coil. When the discharge passes in the vessel, the readings drop back to a smaller value. This drop-back is proportional to the dissipation $q$ in the circuit. The energy absorbed reaches a maximum near the pressure at which the discharge first appears. It steadily decreases and becomes zero again at the pressure at which the discharge disappears.

The measurements discussed by Dr. **Poor** are made for the purpose of classifying the yachts and furnish a basis for handicapping them in racing. From such measurements, made of

the hull, spars and sails, an expression is found for the "theoretical speed," or speed the yacht should make under normal conditions. While every little detail of hull and rigging contributes its part in producing a fast yacht, yet it is manifestly impossible to take account of all such details in finding the "theoretical speed"; only the main factors can be considered. These factors, which enter the rules in common use, are length of hull, sail area and displacement.

It was shown that the rules introduce these factors in such a way as to involve the assumption that speed is proportional to: (*a*) The square root of length; (*b*) the fourth root of sail area; and that the New York Yacht Club rule involves these two assumptions and the additional one that speed is proportional to (*c*) the inverse sixth root of displacement.

Dr. Poor discussed these assumptions in detail and showed that, while there is some apparent basis for the assumption in regard to length, their appears to be no scientific basis for those in regard to sail area and displacement. In fact, the available data seem to point to the conclusion that the assumption in regard to sail area is wrong, that speed is more nearly proportional to square root of sail area. In support of this view the results of many races between two yachts in 1902 and 1903 were used. Dr. Poor called attention to the scientific aspect of the problem, and suggested several lines of experiment, by means of which the relationship between speed and the factors of measurement could be determined.

S. A. Mitchell,
*Secretary.*

## SECTION OF BIOLOGY.

### November 9, 1903.

The November Meeting of the section was held on the 9th of the month at the American Museum of Natural History, Professor Brashford Dean presiding. A business meeting of the Section preceded the scientific program. Professor E. B. Wilson was nominated to the Council as vice-president and chairman of the Section of Biology for the coming year. M. A. Bigelow was re-elected secretary of the section.

Professor **Gary N. Calkins** then gave an illustrated lecture on "THE LIFE-HISTORY OF CYTORYCTES VARIOLÆ, THE CAUSE OF SMALLPOX."

M. A. BIGELOW,
*Secretary.*

## SECTION OF GEOLOGY AND MINERALOGY.

NOVEMBER 16, 1903.

Section met at 8.15 P. M., Professor James F. Kemp presiding. The minutes of the last meeting of the Section were read and approved.

The following officers were elected for the year 1904:

Chairman, Professor James F. Kemp.

Secretary, Edmund Otis Hovey.

Notice was given regarding applications for grants from the Hermann Fund.

The following programme was then offered:

**A. W. Grabau,** "DISCUSSION OF AND SUGGESTIONS REGARDING A NEW CLASSIFICATION OF ROCKS."

**Wallace Goold Levison,** "NOTE ON FLUORESCENT GEMS."

**George F. Kunz,** "MINERALOGICAL NOTES."

SUMMARY OF PAPERS.

Dr. **Grabau** said in part, that all classification ought, as far as possible, to be genetic or according to progressive development. Such a classification is practicable in the biologic sciences, but not in those, which, like minerology, deal with inorganic substances. In developing his theme the speaker suggested the following provisional subdivisions: endogenetic rocks, or those formed by chemical means, and exogenetic or clastic rocks, which are chiefly of mechanical origin. The first group is further subdivided into: pyrogenic, or igneous rocks; hydrogenic or aqueous rocks; biogenic or organic rocks. The hydrogenic and biogenic rocks were each again subdivided into rocks of calcareous, silicious, ferruginous, carbonaceous and miscellaneous composition; and a further subdivision was made into unaltered and altered or metaphoric types.

The exogenic or clastic rocks were divided into autoclastic, hydroclastic, pyroclastic, bioclastic and anemoclastic.

A further subdivision according to texture was, into rudaceous or conglomeratic, arenaceous or sandy, and lutaceous or mud rock.

The next division was according to composition, into two main groups — silicious and calcareous; and finally into unconsolidated and consolidated and metamorphic rock.

In the discussion of the paper Professor **Stevenson** spoke of the value of such a classification through its giving teachers ideas for presentation to their classes regarding the interrelations of rock. Professor **Kemp** spoke of the system being well adapted to geologic study on account of its giving the surroundings in which any specified rock has developed, although it is not practicable to assign a place to every small rock group which is really of mineralogical rather than of geological value.

Mr. **Levison** said: Fluorescence or the property of increasing the wave-length of certain luminous rays enhances the beauty of a few colored gems under conditions which lessen the effectiveness of others that do not possess this property. Garnet, for instance, which is non-fluorescent, loses its rich crimson color and becomes dull gray in pure blue light. On the contrary, most kinds of ruby and ruby spinel, and pink topaz respond to light-rays above the red on account of their fluorescence, and in blue-violet light still display their characteristic tints. The red color of the ruby is somewhat developed by the light of the air-gap spark and an uncovered Crookes tube. It is intensely excited by the cathode rays. Willemite displays a beautiful greenish-yellow color not only in ordinary light rich in the yellow-green rays but also in light consisting chiefly or wholly of the more refrangible colors in which its characteristic color would be effaced but for the possession of fluorescence in high degree. This mineral is excited furthermore by some of the ultra-violet rays and by the Roentgen and Becquerel rays.

Other materials which owe desirable tints to fluorescence are pearl, opal, hyalite, chalcedony and kunzite (the new lilac spo-

dumene). Hiddenite, the green spodumene, seems to be non-fluorescent. Impaired by fluorescence are triphane, a yellowish-green spodumene, which exhibits pink fluorescence in blue light; emerald, which shows crimson fluorescence in the upper part of the spectrum, and diamond, with greenish-blue to blue fluorescence excited by several kinds of energy but more or less masked in ordinary light.

In fluorescent substances excitation produces a certain opalescence or milkiness which is sometimes of sufficient strength to be of importance. It cannot be taken as an indication of impurities in the materials. In the white diamond such a phenomenon is a detrimental quality.

Fluorescence affords a simple and positive method of distinguishing some of the fluorescent gems from imitations. All glass imitations are fluorescent with the color characteristic of glass from which the fluorescent color of the genuine stone differs distinctly. In doublets the cement appears as an opaque film and the components differ in behavior. Artificial pearls of high grade have not been examined, but probably they will behave like the genuine. Artificial or "regenerated" ruby has been examined in a single specimen. It acts like the natural stone in blue light, while with the air-gap spark between iron or aluminum electrodes it has a brighter color than any of the several natural rubies which were examined. The wave-length which excites fluorescence of each substance must eventually be stated.

The following gems were stated to be non-fluorescent: garnet, amethyst, Spanish topaz, yellow Brazilian topaz, sapphire, ordinary beryl, possibly Siamese ruby.

In the discussion of Mr. Levison's paper Professor **Kemp** expressed the hope that there would be a practical outcome from such investigations which would enable those not experts to detect false or artificial gems; while Mr. **Kunz** said that there were simpler ways than the use of fluorescence for the determination of gems, and Professor **D. S. Martin** emphasized the desirability of getting definite information as to the wave-lengths to which gems respond.

In the course of his paper Dr. **Kunz** exhibited white compact garnet from Fresno County, California, associated with the newly described compact vesuvianite, or "californite." In connection with these two compact minerals attention was called to the third compact mineral "pectolite," which was described some years ago by W. P. Blake. Pyroelectric zinc blende associated with wollastonite from Mariposa County, California, also was exhibited.

EDMUND OTIS HOVEY,
*Secretary.*

## SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

NOVEMBER 23, 1903.

The section met on November 23, in conjunction with the American Ethnological Society.

The following paper was presented and read :

**Clark Wissler**, RECENT RESEARCHES ON THE DECORATIVE ART OF THE PLAINS INDIANS.

Dr. **Wissler** said it was demonstrated by specimens and explanations that among the Indians of the plains may be found a type of graphic art that is purely decorative in contrast to a type that is absolutely symbolic. In addition, a transition type occurs in which both the symbolic and the asthetic motives function. The whole of this art is the work of women. In the purely decorative art complex geometric designs are built up from simple geometrical elements. These elementary designs have technical names and are worked into compositions according to recognized principles and standards. In the symbolic art the designs are conventional representations of objects with sacred or mystic associations and are realistic in motive. While a number of conventional designs are used which are known once to have possessed symbolic value and to have originated in realistic motives, the majority of design elements do not appear to have originated in this way. Their occasional use in a symbolic sense is an afterthought and a makeshift.

From which it appears that the graphic art of these Indians, as we find it to-day, is an objective development in contrast to the subjective symbolism of other tribes.

JAMES E. LOUGH,
*Secretary.*

## BUSINESS MEETING.

DECEMBER 7, 1903.

The Academy met at 8:15, Vice-President Dean presiding. The minutes of the last business meeting were read and approved.

The Secretary reported from the Council as follows: that the following Active Members had been nominated as candidates for election as Fellows — Isaac Adler, M.D., Edward K. Dunham, M.D., William Harper Davis, Miss Ida N. Ogilvie, Ph.D., and Charles H. Townsend.

That the following nominations for officers for the coming year had been made:

President, Edmund B. Wilson.

Vice-Presidents: James F. Kemp, L. M. Underwood, C. L. Poor, F. J. E. Woodbridge.

Corresponding Secretary, R. E. Dodge.

Recording Secretary, H. E. Crampton.

Treasurer, C. F. Cox.

Librarian, R. W. Tower.

Editor, C. L. Poor.

Councilors (to serve three years): Livingston Farrand, E. O. Hovey.

Finance Committee: J. H. Hinton, C. A. Post, H. F. Osborn.

That the Annual Meeting would consist of a formal meeting for the election of Fellows and Officers, for the reading of the annual reports of the officers for the past year, etc., and that this would be followed by a dinner to be served in the Museum building. Full notices would be sent to members in the usual manner.

The following candidates for active membership, approved by the Council, were duly elected:

Oswald Speir, 310 West 94th Street.

Emil Heuel, M.D., 1 West 94th Street.

On recommendation of the Council, the following Active Member was elected a Fellow:

Ralph W. Tower.

### Miscellaneous Business.

The notice of the Academy was called to the death of Dr. H. Carrington Bolton, a former President of the Academy, by Professor D. S. Martin, with a statement that it would be eminently fitting for the Academy to take formal action in recognition of the long services of Dr. Bolton to the Academy. It was voted that the Chairman appoint a Committee of three to prepare a suitable minute relating to Dr. Bolton's death. The Chairman appointed D. S. Martin, N. L. Britton, and E. B. Wilson.

The Academy then adjourned.

H. E. Crampton,
*Recording Secretary.*

## SECTION OF BIOLOGY.

### December 7, 1903.

The December meeting was held on the seventh of the month, Professor Bashford Dean presiding. Professor Wilson declined the nomination for the vice-presidency and chairmanship of the Section which was made at the November meeting; and Professor L. M. Underwood was by unamious vote nominated as the candidate from the Section to be presented at the annual meeting for election of officers of the Academy.

The following scientific program was presented:

**E. B. Wilson,** An Experimental Study of the Germ-Regions in the Molluscan Egg.

**A. G. Mayer,** The Coral Reefs of the Bahamas (illustrated).

### Summary of Papers.

Dr. **Mayer** said that the shallow Bahama banks are veritable submarine deserts covered with finely divided silt and fragments of the calcareous remains of marine animals and plants. The corals grow in clusters chiefly on the outer edges of the banks and may be compared to oases in the desert.

The water of the banks is generally charged with a flocculent mass of silt which is fatal to most of the pelagic animals. Accordingly the Bahamas have only about half as many species of pelagic animals as the Tortugas, Florida.

The exceptional richness of the Tortugas' fauna is also due to the drift from the Gulf Stream caused by prevailing northeast and southeast winds, while the fauna of the Bahamas is depleted from the same cause. In other words the Bahamas lie on the wrong side of the Gulf Stream for the study of pelagic life. About one-half of the pelagic forms of the Bahamas are equally abundant at the Tortugas; but about one-quarter of the remainder are more abundant at the Bahamas, and a few of these seem to be confined exclusively to this region.

The Bahamas are richer in species of corals and actinians than the Tortugas, this being due to the fact that the coral-reefs of the Tortugas were largely killed by a drift of dark-colored water which passed over them in October, 1878, and have only partially recovered. No more favorable situation for the study of pelagic life has been discovered in the tropical Atlantic than that of the Tortugas, Florida.

Prof. **Wilson's** paper is to be published in a forthcoming number of the *Journal of Experimental Zoölogy*.

M. A. Bigelow,
*Secretary*.

## SECTION OF GEOLOGY AND MINERALOGY.

December 14, 1903.

Section met at 8:15 P. M., Professor J. F. Kemp presiding.

The minutes of the last meeting were read and approved.

The following program was then offered:

**Herschel C. Parker**, EXPLORATIONS AND FIRST ASCENTS IN THE CANADIAN ROCKIES.

**George F. Kunz**, GEM MINERALS OF SOUTHERN CALIFORNIA. (Read by title.)

**George F. Kunz**, CLACKAMAS METEORIC IRON. (Read by title.)

SUMMARY OF PAPERS.

Professor **Parker's** paper occupied the evening, and consisted of an illustrated lecture describing the section of the Rocky Mountains in British Columbia and Alberta known as the "Canadian Alps."

In a brief introduction an explanation was given of the physical characteristics which determine the Alpine nature of mountain ranges and it was pointed out that the Rocky Mountains of Canada may justly be termed the "Switzerland of America."

A series of more than 100 lantern slides was shown, many of them illustrating first ascents made by the lecturer. These summits were Mt. Dawson, the highest peak of the Selkirks, Mt. Goodsir, one of the highest and most difficult peaks in British Columbia, Mt. Lefroy, Mt. Hungable ("the Chieftain"), Mt. Deltaform and Mt. Biddle, these latter peaks being situated in Alberta near Lake Louise. The summits of some of these mountains were previously thought to be practically inaccessible and the climbs were attended with the greatest difficulties. Mt. Lefroy was climbed by the lecturer in 1897, Mt. Dawson in 1899 and the remaining four summits during the past season. The lecturer also briefly described an interesting trip of about 100 miles north of the railroad to Wilcox Pass where the Saskatchewan and Athabasca Rivers take their rise.

The papers by Dr. **Kunz** have been published in *Science*, N. S., Vol. XIX, January, 1904, pp. 107–108.

EDMUND OTIS HOVEY,
*Secretary.*

## ANNUAL MEETING.

DECEMBER 21, 1903.

The Academy met for the Annual Meeting at 6.45 P. M., President Cattell in the Chair.

The accompanying reports of officers for the past year were called for and presented, in the following order: Corresponding Secretary, Recording Secretary, Treasurer, Librarian, and Editor.

No Honorary or Corresponding Members were elected.

The following Active Members were elected Fellows of the Academy, on the nomination of the Council:

Isaac Adler, M.D.,

William Harper Davis,

Edward K. Dunham, M.D.,

Ida H. Ogilvie, Ph.D.

Charles H. Townsend.

The election of officers for the year 1904 was then held, tellers being appointed, ballots distributed and the votes counted. The following officers were elected:

President, Edmund B. Wilson.

Vice-Presidents, James F. Kemp, Lucien M. Underwood, Charles Lane Poor, F. J. E. Woodbridge.

Corresponding Secretary, R. E. Dodge.

Recording Secretary, Henry E. Crampton.

Treasurer, Charles F. Cox.

Librarian, Ralph W. Tower.

Editor, Charles Lane Poor.

Councilors (three years), Livingston Farrand, E. O. Hovey.

Finance Committee, John H. Hinton, C. A. Post, Henry F. Osborn.

The meeting then adjourned to the Hotel Endicott; it was continued in the form of a dinner, at which fifty members of the Academy and their friends were present.

The accompanying report of the special Committee appointed at the meeting of the Academy of December was presented by the Chairman of the Committee, Professor D. S. Martin.

Brief addresses were made by the retiring President, Professor Cattell, by the President-elect, Professor Wilson, and by the past-Presidents of the Academy, Professor Woodward, Professor Osborn, and Professor Stevenson.

The meeting then adjourned.

HENRY E. CRAMPTON,
*Recording Secretary.*

## REPORT OF THE CORRESPONDING SECRETARY.

The Corresponding Secretary would report that there are at present on the rolls of the Academy 39 Honorary Members and 191 Corresponding Members. During the year the list of Honorary and Corresponding Members has been corrected by comparing it with the latest editions of "Minerva," "Who's Who" and other authoritative publications. The list as corrected was printed by the Academy during the summer. Letters have since been written to all Honorary and Corresponding Members asking for additional information or necessary corrections. The names of those who do not reply for two consecutive years will be dropped from the lists.

Respectfully submitted,

RICHARD E. DODGE,
*Corresponding Secretary.*

## REPORT OF THE RECORDING SECRETARY.

Since the last Annual Meeting, twenty-nine regular meetings of the several sections have been held at which seven lectures and fifty-one stated papers have been presented. The titles were distributed as follows:

*Section of Astronomy, Physics and Chemistry.*

| | | | |
|---|---|---|---|
| Astronomy, | 4 papers. | | |
| Chemistry, | 1 paper. | | |
| Physics, | 7 papers. | 1 lecture. | |
| | | | 12 papers, 1 lecture. |

*Section of Biology.*

| | | | |
|---|---|---|---|
| Botany, | 1 paper. | | |
| Palæontology, | 1 " | | |
| Zoology, | 11 papers. | 2 lectures. | |
| | | | 13 papers, 2 lectures. |

*Section of Geology and Mineralogy.*

| | | | |
|---|---|---|---|
| Geology, | 7 papers. | | |
| Hydrography, | | 1 lecture. | |
| Mineralogy, | 2 " | | |
| Physiography, | 1 paper, | 2 lectures. | |
| | | | 10 papers, 3 lectures. |

*Section of Anthropology and Psychology.*

Anthropology, 8 papers, 1 lecture.
Psychology, 18 "

26 papers, 1 lecture.

Total, 51 papers, 7 lectures.

Through the courtesy of the authorities of the American Museum in permitting the use of the Great Hall of the Museum, it has been possible to develop the work of several sections by having public lectures delivered on topics of general scientific interest. Particular mention may be made of the lectures presented by Professor Calkins on the Organism of Small-pox, by Dr. Hovey on his observations of Mont Pele and by Professor Parker on his Explorations in the Canadian Rockies. Mention may also be made of Dr. Hollister's account of the Hydrographic work of the U. S. Geological Survey, of Professor Dean's report on zoological work in Japan, and of Dr. Kunz's demonstration of radium and its effects on various minerals.

Another extension of the work of the Academy demands special attention, namely that in the Section of Anthropology and Psychology. This section has met in conjunction with the New York Branch of the American Psychological Association, at times outside the City of New York, and at these meetings a more extended series of varied papers has been presented than would be possible at ordinary sectional meetings.

The membership of the Academy has somewhat decreased during the past year. At present there are two hundred and eighty-seven Active Members, of whom one hundred and twenty-eight are Fellows, while the election of five Fellows is pending. Eight Members have resigned, and eight new Members have been elected, while thirteen members have died since the last Annual Meeting. The Academy notes with sorrow the death of several men, devoted to scientific research and to the furtherance of true scientific progress, whose names stood for true ideals of service in behalf of mankind. The Academy and the community at large suffers from the loss of H. Carrington Bolton, one of its past Presidents, of Andrew H. Green, Will-

iam E. Dodge, Cornelius Van Brunt, Albert R. Leeds, and Abram S. Hewitt.

HENRY E. CRAMPTON,
*Recording Secretary.*

## REPORT OF THE TREASURER.

NEW YORK, December 21, 1903.

TO THE NEW YORK ACADEMY OF SCIENCES:

*Gentlemen* — As required by the by-laws, I herewith submit a statement of my receipts and disbursements since my last annual report, and a balance sheet from my ledger, as of this date.

Respectfully yours,
C. F. COX,
*Treasurer.*

Examined and found correct,

JOHN H. HINTON,
*For the Financial Committee.*

### RECEIPTS.

| | | |
|---|---|---|
| Balance as per last annual report......... | | $3,756.09 |
| Annual dues for 1900,........ | $ 30.00 | |
| " 1901,........ | 60.00 | |
| " 1902,........ | 200.00 | |
| " 1903,........ | 1,930.00 | |
| " 1904,........ | 30.00 | 2,250.00 |
| Initiation fees,........................ | | 45.00 |
| Interest at 4½ per cent. on Bond and Mortgage of $12,000,..................... | | 540.00 |
| Interest on deposits in Bank,............ | | 61.23 |
| | | $6,652.32 |

### DISBURSEMENTS.

| | | | |
|---|---|---|---|
| Cost of Publications,........... | $703.66 | | |
| Less Sales,................ | 59.98 | 643.68 | |
| Expenses of Recording Secretary, ........ | | 261.09 | |
| " Corresponding Secretary,..... | | 5.00 | |
| " Librarian,................ | | 276.70 | |
| " Treasurer,................ | | 21.23 | |
| General Expenses,.................... | | 80.00 | 1,287.70 |
| Balance on hand,.................. | | | $5,364.62 |

BALANCE SHEET.

| | Dr. | Cr. |
|---|---|---|
| Permanent Fund, .................. | | $10,371.43 |
| Publication " .................. | | 1,823.99 |
| Audubon " .................. | | 1,897.25 |
| Income, Permanent Fund, .......... | | 676.31 |
| Income, Publication Fund, .......... | | 113.77 |
| Income, Audubon Fund, ............ | | 115.99 |
| General Income, .................. | | 2,006.18 |
| Investment on Bond and Mortgage, .. | $12,000.00 | |
| Cash on hand ..................... | $ 5,364.62 | |
| | $17,364.62 | $17,364.62 |

NEW YORK, December 21, 1903.

## REPORT OF THE LIBRARIAN.

In accordance with the agreement between the New York Academy of Sciences and the American Museum of Natural History, the library of the Academy was on March 3, 1903, transferred to the custody of the Museum. Since that time the attention of the Librarian has been confined to the care of incoming exchanges and the correspondence of the office. Mr. William M. Erb has continued as the assistant in charge of the details of the work. The Librarian of the Museum has been engaged in arranging the Academy library and it is now in better condition for reference then ever before, and is available at any time to members of the Academy.

In laying down his office, the Librarian would call the especial attention of the Academy to the advisability of revising the exchange list, in consultation with the authorities of the American Museum, in order to avoid the useless duplication of minor exchanges brought about by the union of the two libraries.

Respectfully submitted,

LIVINGSTON FARRAND,

*Librarian.*

## REPORT OF THE EDITOR.

During the year 1903 the Academy printed and issued the following publications:

Part III, Vol. XIV, of the Annals, containing a paper by John Cutler Torrey, entitled, "The Early Embryology of *Thalassema mellita* (Conn.)." This was issued in October, and consisted of 81 pages, 2 plates and 10 text-figures.

Part I, Vol. XV., of the Annals, containing the records of the meetings of the New York Academy of Sciences, January, 1902, to December 1902, by Henry E. Crampton, Recording Secretary. This was issued in September and consisted of 152 pages.

Both of these publications were mailed to every member of the Academy.

Vol. XIV, No. 4, and Vol. XV, No. 2, are in press and will soon be issued.

Charles Lane Poor,
*Editor.*

## HENRY CARRINGTON BOLTON.

The undersigned, appointed at the meeting of December 6, 1903, a Committee to prepare a minute and resolutions concerning the death of H. Carrington Bolton, long an active member of the Academy, having held various offices therein, including the office of President in 1893 herewith present the following report:

Whereas, it has pleased the great Disposer of all events to remove from this world our late friend and associate, Dr. Henry Carrington Bolton, on the 19th day of November last, therefore,

*Resolved*, that in the name of the New York Academy of Sciences, as well as in the fulness of our own personal feeling, we take a mournful pleasure in expressing our profound sorrow at his unexpected demise in the full activity of his powers, and our keen sense of the loss thus caused to American science.

*Resolved*, that we recall with warmest interest his breadth of culture, his cordiality of intercourse, his devotion to science, his untiring activity, and his dignity and uprightness of personal character.

*Resolved*, that we bear our grateful witness to his long and faithful services in and to the New York Academy of Sciences, as Councilor and as Secretary through many years, and as President in 1893; since which time he has resided principally at Washington, and has thus become less well-known to the younger body of members.

*Resolved*, that these resolutions be entered upon the records of the Academy and that a copy thereof be sent to his widow by the Secretary.

DANIEL S. MARTIN, *Chairman*,
N. L. BRITTON,
E. B. WILSON.

# PUBLICATIONS

OF THE

# NEW YORK ACADEMY OF SCIENCES

[LYCEUM OF NATURAL HISTORY 1818–1876]

---

The publications of the Academy consist of two series, viz :—

(1) **The Annals** (octavo series), established in 1823, contain the scientific contributions and reports of researches, together with the records of meetings, annual exhibitions, etc.

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(2) **The Memoirs** (quarto series), established in 1895, are issued at irregular intervals. It is intended that each volume shall be devoted to monographs relating to some particular department of science. Volume I is devoted to Astronomical Memoirs, Volume II, to Zoölogical Memoirs, etc. The price is one dollar per part, as issued.

All publications will hereafter be sent free to fellows and members who desire to receive them, but other fellows and members will only receive the Records, issued as a separate from the Annals. The Annals will be sent, as before, to honorary and corresponding members desiring them.

Subscriptions and inquiries concerning current and back numbers of any of the publications of the Academy should be addressed to

THE LIBRARIAN
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Columbia University
New York City.

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| | | | |
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# CONTENTS OF VOL. XV, PART II

VOL. XV PART III

# ANNALS

OF THE

# NEW YORK

# ACADEMY OF SCIENCES

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Editor:

CHARLES LANE POOR

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The New Era Printing Company

Lancaster, Pa.

# NEW YORK ACADEMY OF SCIENCES

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## SESSION OF 1904

The Academy will meet on Monday evenings at 8.15 o'clock, from October to May, in the American Museum of Natural History, **77th Street and Central Park, West.**

[ANNALS N. Y. ACAD. SCI., Vol. XV, No. 3, pp. 217–297, Nov. 30, 1904.]

# RESEARCHES AS TO THE IDENTITY OF THE PERIODIC COMET OF 1889–1896–1903 (BROOKS) WITH THE PERIODIC COMET OF 1770 (LEXELL).

CHARLES LANE POOR.

CONTENTS.

## INTRODUCTION.

1. This comet was discovered by William R. Brooks, at Geneva, New York, July 6, 1889, and was observed until January, 1891. It was a faint telescopic object, never visible to the naked eye, and showing no striking physical characteristics; but of interest on account of the orbit it described and of the many problems in astro-mechanics which have arisen in the attempt to trace its past history. After a very few observations had been made, it was recognized as a periodic comet, travelling in an orbit of about seven years, and a very interesting member of Jupiter's so-called family. Chandler[1] was the first to investigate its history and show that its orbit had been changed radically by a close approach to Jupiter in 1886; that before that time the comet was moving in an entirely different orbit from that in which it has since moved. The interest in the problem was still further increased by the statement of Chandler that the comet of 1889 was probably identical with the lost comet of 1770 (Lexell). Chandler's results, however, depended upon observations extending over a period of three months only, and the perturbations during the years 1886 to 1889 were neglected. In this paper Chandler gave the period of the comet previous to 1886 as 26.9 years, and upon the substantial correctness of these figures depended his conclusions as to the identity with Lexell's comet.

2. Lexell's comet was first seen by Messier on the night of June 14–15, 1770. He at first thought it to be a part of the nebula in the constellation Sagittarius but after a few nights he recognized its cometary character. At this time it was faint and invisible without the aid of a telescope, and appeared as a nebulosity about 5′ 23″ in diameter. On June 21, however, it became visible to the unaided eye, and three days later was as bright as a second magnitude star. It was now seen to have an ill

[1] "The Action of Jupiter in 1886 upon Comet d, 1889, and the Identity of the latter with Lexell's Comet of 1770," *Astr. Jour.*, 205, p. 100.

defined head, or nucleus, of about 80″ diameter and a tail which reached its greatest length on July 1, when it extended 2° 23′. On July 4 the comet disappeared in the rays of the sun, not to reappear until August 4, after which it could be seen by the unaided eye until the 26th of August and in the telescope until October 3, when its distance from the earth and sun became so great as to render it invisible with the instruments of that day.

Parabolic elements were calculated by Pingrè, Lambert and others. These, however, did not satisfy all the observations and it remained for Lexell to prove that the comet was travelling in an elliptic orbit of 5.6 years' period. Lexell further showed, in answer to various objections to the theory of elliptic motion, that in May, 1767, the comet had passed very close to Jupiter and that then its orbit had probably been greatly changed—changed sufficiently to render it visible in 1770. He further predicted a second approach of the comet to Jupiter in August, 1779, and stated that the occurrence might prevent the return of the comet in 1781 or 1782. The comet was sought vainly in those years, and has never been observed since.

In 1844 LeVerrier[1] presented to the Académie des Sciences his researches upon the motion of this comet and upon the character of the disturbances by Jupiter in 1779. This paper is a complete treatise upon the subject, discussing every phase of the matter in a most thorough manner. Unfortunately, however, LeVerrier found that the old observations were so crude that a definitive determination of the orbit was impossible. A comparison of the observed and computed places showed errors in the original observations amounting in many instances to ten or even fifteen minutes of arc. Unable to determine the exact elements of the orbit, LeVerrier expressed the elements which best represented the motion of the comet in terms of an unknown and indeterminate quantity, $\mu$. This quantity is carried through all the calculations and the paper concludes with tables showing a number of possible orbits of the comet after its great disturbance by Jupiter in 1779.

[1] "Théorie de la Comète Periodique de 1770," *Annals de l' Observatoire de Paris*, Tom. III, p. 203.

3. Lexell's comet underwent its notable disturbance in August, 1779, and, moreover, this disturbance took place in that part of Jupiter's orbit in which the Brooks comet suffered its change of elements in 1886. Between these two appulses there intervened a period of 107 years, which must be accurately accounted for in order to establish the identity of these two bodies. That is, during this interval the comet must have made two, three or four complete revolutions about the sun, and its period, therefore, must have been one half, a third or some aliquot part of 107 years. Chandler, in the above mentioned paper,[1] found that the period of the Brooks comet previous to 1886 was 26.9 years, very approximately one quarter of the 107 years to be accounted for. The possibility of the comet having made three revolutions during this period can be eliminated, according to Chandler, as this would have brought the comet and Jupiter together in 1815 and 1850, at which times the perturbations would have been enormous. The interval can hardly be accounted for upon any other supposition than that of four revolutions of the comet being equal to nine of Jupiter's.

A comparison of the elements of Lexell's comet, subsequent to its disturbance in 1779, as given by LeVerrier, with those of the Brooks comet previous to 1886, as given by Chandler, show a striking likeness. The longitude of the node is nearly the same for both, 175° for Lexell against 177° for Brooks; the inclinations differ by less than 4° and the eccentricities are not far apart. Again, the heliocentric longitudes, within which the attraction of the sun was overborne by the influence of Jupiter are nearly the same for both comets. Taking all these points of resemblance into consideration and assuming the substantial correctness of the period (26.9 years) he deduced, Chandler concluded that there is "an overwhelmingly strong presumption in favor of the identity of these two comets."

4. The question of identity was investigated in an entirely different manner by Schulhof,[2] who made use of a criterion

[1] *Astr. Jour.*, No. 205.

[2] *Bulletin Astronomique*, November, 1889.

formulated by Tisserand. By an investigation of the path of a comet through a planet's "sphere of activity," Tisserand derived a function, $n$, of the comet's elements and of those of the disturbing planet, which remains practically unaltered, however great the change in the individual elements. The action of Jupiter, for example, even repeated at several very close appulses, can cause but a very slight change in the numerical value of this function. Schulhof found that the $n$'s for Lexell's and for Brooks' comets differed, and that the comets, therefore, could not be identical.

This criterion, however, only holds if the comet has been disturbed by a single planet, and in a later paper[1] Schulhof discussed the possibility of the identity of the two comets, assuming that there had been disturbances by both Jupiter and Saturn. By assuming the identity of the two comets, he was able to deduce, by means of the criterion, the most probable orbit of the body between 1779 and 1886. He thus found that, if these bodies are one and the same, its period must have been about 32 years from 1779 to 1849, at which time it passed close to Saturn, suffered large disturbances and had its period increased to about 42 years. Thus the comet made three revolutions in the 107 years to be accounted for, but three revolutions of unequal duration.

5. In the latter part of 1889 I took up this problem and attempted to solve the question of identity between these two remarkable bodies. I based my work on an orbit obtained by the method of the variation of geocentric distances from ten normal places between July 1889 and December 1890. The results of this investigation[2] differed greatly from those obtained by Chandler and left the matter in a very unsettled state. Meanwhile, Bauschinger undertook the determination of the definitive elements of the comet's orbit, and upon the publication of his results,[3] I began a reinvestigation of the entire subject and determined to do the work in as thorough a manner as possi-

[1] *Bulletin Astronomique*, December, 1889.

[2] *Astr. Jour.*, No. 244.

[3] "Untersuchungen über den periodischen Kometen 1889 V (Brooks)," I Theil.

ble. Unfortunately, however, Bauschinger found a direct solution of his normal equations impossible, the last element determined being quite uncertain. Hence the final elements as given in his paper were still subject to an uncertainty, very slight indeed, but enough to affect to some extent the character of the appulse with Jupiter. In order to take account of this uncertainty and to show our actual knowledge of the movements of this interesting body, I solved his equations anew and expressed the elements in terms of an indeterminate quantity, and this indeterminate quantity, $\nu$, I carried through my entire work. The results of this investigation, published in 1893,[1] left the question of identity still unsettled, although the results pointed very strongly to the non-identity of the two bodies.

In the hope that the first few observations of the second appearance of the body in 1896 would completely settle the question, I carried the elements forward, and found an ephemeris for the time of its return.[2] The comet was rediscovered by Javelle at Nice on June 20, 1896, very close to the predicted place, and from the observations a close approximation to the value of the indeterminate, $\nu$, was made.[3] With this a better determination of the character of the appulse to Jupiter in 1886 was made, and the result seemed to conclusively prove the non-identity of the two bodies.

6. Bauschinger carried on his investigations and determined in a most painstaking and satisfactory manner the elements which best represent the observations of the comet during the two appearances of 1889–90 and 1896–97.[4] The final elements obtained by him differed but slightly from those I had obtained, as above mentioned, and, therefore, the conclusions which I had reached were not altered by his later investigations. The elements which he obtained, however, did not represent the obser-

[1] "Researches upon Comet 1889 V," *Astr. Jour.*, Nos. 302, 303.

[2] "Preliminary Note on the Reappearance of Comet 1889 V," *Astr. Jour.*, No. 320, p. 63.

[3] "Note on the Periodic Comet of Brooks and Javelle," *Astr. Jour.*, No. 380, p. 175.

[4] "Untersuchungen über den periodischen Kometen 1889 V, 1896 VI (Brooks)," 2 Theil.

vations with the accuracy that could be desired. As pointed out by Bauschinger, the differences between the observed and computed places of the comet varied periodically. In the first appearance, 1889–90, the point of the comet which was measured, appeared a little south, and in the second appearance, 1896–97, a little north of the places computed from the mean path, and the total differences amounted to about $3''.0$. Bauschinger explained these discrepancies as due to one of two causes. First, that different portions of the comet were measured during the two appearances, owing to local changes in the brightness of the object. Second, actual changes in the position of the nucleus of the comet, due to perturbations by the smaller, and in the latter appearance, invisible, companions.

The elements, as deduced by Bauschinger, were carried forward by Neugebauer, and an ephemeris computed for the third appearance in 1903. The comet was rediscovered on August 18, 1903, by Aitkin, at the Lick Observatory and was found to be very close to the predicted place; the difference between observation and theory being about $24^s$ in Right Ascension and $1'\ 30''$ in Declination.

7. It seemed desirable to correct my work, heretofore mentioned, by means of the latest data, and to collect and publish in final form the results of my various investigations upon the appulse to Jupiter in 1886 and the consequent changes in the orbit of this body. In this I was greatly aided by a grant of money by the Trustees of Columbia University, which was used in employing assistant computers. The first step was the selection of the elements on which to base my investigation and here at the outset I was confronted by a difficulty. A comparison of Bauschinger's elements with the positions of the body at the time of discovery in 1903 showed that these elements were not all that could be desired, and a redetermination of the elements was decided upon as a preliminary. In this redetermination all the data from the first two appearances were used and the elements deduced therefrom were checked with one or two normal places from the 1903 appearance. Thus the elements may be regarded as definitive for the appearances

of 1889 and 1896, but not for the appearance of 1903. It was not deemed advisable nor necessary to wait until the present appearance shall be over so as to include all the observations of this appearance, as this would probably delay the work for a year or more.

The present paper, therefore, naturally divides itself into two parts:

1. The determination of the elements which best represent the motion of the comet at the time of its discovery in 1889.

2. Using the elements, thus determined, as a basis, the discussion of the action of Jupiter upon the comet in 1886, and a determination of the most probable orbit previous to that date. In this part is included the discussion of the possibility of the identity of this comet with that of Lexell.

# PART I.

## Definitive Determination of the Elements from the Appearances of 1889–90 and 1896–97.

### A. — *Preliminary Correction to Elements.*

8. The elements, deduced by Bauschinger[1] from the first appearance of the comet in 1889–90, were slightly indeterminate. I solved his equations anew and expressed the elements in terms of an indeterminate quanity, $\nu$, the limits of variation of which were placed at $\pm 40$.[2] These elements were carried forward to the time of perihelion passage in 1896, the indeterminate, $\nu$, being retained and carried through the computations. During the interval 1889–97, the perturbations of Jupiter, Saturn and the Earth were taken into account; those due to Mars were considered for a short period only. With the resulting elements,[3] an ephemeris of the comet was computed for the possible times of visibility in the years 1895 and 1896.

The comet was rediscovered by Javelle at Nice on June 20, 1896, and a comparison of his observation with the above mentioned ephemeris gave the following differences, in the sense observed *minus* computed,

$$\Delta\alpha = -0^{m}\ 24^{s}.61$$
$$\Delta\delta = -2'36''.00$$

This observation was sufficient to determine a close approxima-

[1] "Untersuchungen über den periodischen Kometen 1889 V (Brooks)," 1 Theil; "Definitive Bahnbestimmung des Haupt-Kometen aus der Erscheinung 1889 bis 1891."

[2] "Researches upon Comet 1889 V," *Astr. Jour.*, No. 302, p. 123.

[3] "Preliminary note on the Re-appearance of Comet 1889 V," *Astr. Jour.*, No. 320, p. 63.

tion to the value of $\nu$, and thence the values of the elements themselves. The elements as thus determined were,[1]

ELEMENTS I.

Epoch, 1896 October 23.5, Greenwich Mean Time.

$$
\begin{array}{rrrrl}
\mu = & 499''.9877 & & & \\
\pi = & 1^\circ & 48' & 53''.69 & \\
\Omega = & 18 & 1 & 7\ .76 & \\
i = & 6 & 3 & 34\ .08 & \Big\} 1896.0 \\
\omega = & 343 & 47 & 45\ .93 & \\
\phi = & 27 & 59 & 56\ .39 & \\
M_0 = & 358 & 22 & 49\ .23 &
\end{array}
$$

With these elements an ephemeris of the comet was computed and published in *Astronomical Journal*, Nos. 383, 386, 389.

A later and fuller comparison of the ephemeris with the observed places of the comet showed that Elements I did not represent the motion as well as had been expected. Five normal places of the two appearances were formed and from them corrections found to the mean daily motion, $\mu$, and to the mean anomaly of epoch, $L$. The corrections thus found were,

$$
\begin{aligned}
\Delta\mu &= -\,0''.004 \\
\Delta L &= +\,5''.00
\end{aligned}
$$

Applying these corrections to ELEMENTS I, I have:

ELEMENTS II.

Epoch, 1896 October 23.5 Greenwich Mean Time.

$$
\begin{array}{rrrrl}
\mu = & 499''.9837 & & & \\
L = & 0^\circ & 11' & 47''.92 & \\
\pi = & 1 & 48 & 53\ .69 & \\
\Omega = & 18 & 1 & 7\ .76 & \Big\} 1896.0 \\
i = & 6 & 3 & 34\ .08 & \\
\phi = & 27 & 59 & 56\ .39 & \\
M_0 = & 358 & 22 & 54\ .93 &
\end{array}
$$

[1] "Note on the Periodic Comet of Brooks and Javelle," *Astr. Jour.*, No. 380, p. 175.

## *Computation of Perturbations.*

9. In order to connect the elements of the three appearances with the greatest precision, I had the perturbations for the intervals 1889–1896 and 1896–1903 recomputed. The method of the Variation of Constants was adopted and ELEMENTS II were used as the basis of computation. The perturbations of Earth, Mars, Jupiter and Saturn were taken into account; the intervals of computation varying for the different planets and elements. A uniform interval of 40 days was adopted for all the elements excepting $\mu$ and L. As these elements are of the most importance and the perturbations large, an interval of 20 days was used in the computations for the Earth and Jupiter.

The computations were made in the following manner. The perturbations of the elements, as originally computed and as given in my papers in the *Astronomical Journal*, were first integrated for each date of computation and the resulting perturbations applied to Elements II, thus were formed the osculating elements for each date of computation. With these varying elements the perturbations were computed, using the formulas as given by Oppolzer. The masses of the planets, as adopted, follow:

Earth, $\dfrac{1}{328016}$ (Newcomb.)

Mars, $\dfrac{1}{2680337}$

Jupiter, $\dfrac{1}{1047.35}$ (Newcomb.)

Saturn, $\dfrac{1}{3501.6}$ (Bessel.)

The epoch of osculation adopted was,

1896, October 23.5 Greenwich Mean Time.

The perturbation of the Mean Longitude was found in the form,

$$\Delta L = (\Delta L)_{\mathrm{I}} + (\Delta L)_{\mathrm{II}}$$

where $(\Delta L)_1$ is the perturbation of the Mean Longitude of the epoch and

$$(\Delta L)_{11} = \int\int \frac{d\mu}{dt}\, dt^2.$$

The integrated perturbations, as thus computed, are given in the following tables :

### Table I.

Perturbations.

1896 October 23.5 to 1889 September 30.5.

| | Earth. | Mars. | Jupiter. | Saturn. | |
|---|---|---|---|---|---|
| | ″ | ″ | ″ | ″ | ″ |
| $\Delta\pi$ | − 1.958 | + 0.207 | − 275.942 | −248.460 | − 526.153 |
| $\Delta\Omega$ | + 0.254 | − .193 | + 155.053 | + 11.257 | + 166.757 |
| $\Delta i$ | + 0.012 | + .018 | + 25.320 | + 10.270 | + 35.620 |
| $\Delta\phi$ | − 0.169 | − .555 | + 257.370 | + 57.977 | + 314.623 |
| $\Delta L_1$ | −10.860 | −1.289 | + 695.137 | +199.357 | + 882.345 |
| $\Delta L_{11}$ | −54.291 | −7.850 | −1538.055 | + 54.160 | −1546.090 |
| $\Delta\mu$ | + 0.00163 | +0.00345 | + 1.61605 | + 0.07849 | + 1.69962 |

1896 October 23.5 to 1903 September 18.5.

| | Earth. | Mars. | Jupiter. | Saturn. | |
|---|---|---|---|---|---|
| | ″ | ″ | ″ | ″ | ″ |
| $\Delta\pi$ | − 2.599 | −0.716 | −517.656 | −57.014 | −577.985 |
| $\Delta\Omega$ | − .644 | − .098 | − .195 | −17.416 | − 18.343 |
| $\Delta i$ | − .764 | − .006 | + 8.402 | + 0.520 | + 8.152 |
| $\Delta\phi$ | − .521 | − .059 | + 55.177 | +12.727 | + 67.324 |
| $\Delta L_1$ | + 8.212 | + .292 | +933.102 | +13.873 | +955.479 |
| $\Delta L_{11}$ | +50.216 | +4.452 | +788.525 | +44.164 | +887.355 |
| $\Delta\mu$ | − 0.00153 | +0.00022 | − 0.24295 | + 0.00433 | − 0.23973 |

10. It is of interest to compare the values of the perturbations thus found with those given, for the same interval, by Bauschinger. These latter values were computed by Neugebauer, and Bauschinger's Elements V[1] were made the basis of the computation. In this work the Osculating Epoch was taken as of 1889 October 8.0, Berlin M. T., and the computations were made at a uniform interval of forty days. This brings a date of computation on October 11.0, 1896, for which

[1] "Untersuchungen uber den periodischen Kometen 1889 V, 1896 VI (Brooks)," 2 Theil. "Die Erscheinung 1896–97 und ihre Verbindung mit der vom Jahr 1889–90."

date Bauschinger's tables give the integrated values of the perturbations. I could thus take directly from his tables without interpolation the values of the perturbations for the interval between 1889 October 8.0 and 1896 October 11.0.

The values of the perturbations as determined by my new computation for this interval can be taken from my tables by interpolation. Interpolating thus and comparing my results with those of Bauschinger, as taken directly from his tables, I find,

INTERVAL 1889 OCTOBER 8.0 TO 1896 OCTOBER 11.0.

| Bauschinger. | Poor. | B *minus* P |
|---|---|---|
| $\Delta i = -$ 35.78 | $-$ 35.46 | $-$ 0.32 |
| $\Delta \Omega = -$ 166.60 | $-$ 166.52 | $-$ 0.08 |
| $\Delta \pi = +$ 525.73 | $+$ 525.21 | $+$ 0.52 |
| $\Delta \varphi = -$ 312.08 | $-$ 312.86 | $+$ 0.78 |
| $\Delta M = -$ 4222.22 | $-$ 4223.97 | $+$ 1.75 |
| $\Delta \mu = -$ 1.70871 | $-$ 1.70879 | $+$ 0.00008 |

The differences are all extremely small, with the exception of $\Delta M$. This is accounted for, however, by the difference in methods: Bauschinger computed the perturbations in $M$ directly, while I computed those of $L$, and the number given above for my perturbation in $M$ was found indirectly from the values given in my tables for $L$ and $\pi$.

Not only do the total results agree closely, but the agreement for the separate planets is also marked, as is shown by the following comparison of the perturbations of the mean motion.

| | Bauschinger. | Poor. | B *minus* P. |
|---|---|---|---|
| Earth | $-$ 0.00232 | $-$ 0.00192 | $-$ 0.00040 |
| Mars | $-$ 0.00346 | $-$ 0.00355 | $+$ 0.00009 |
| Jupiter | $-$ 1.62464 | $-$ 1.62501 | $+$ 0.00037 |
| Saturn | $-$ 0.07829 | $-$ 0.07831 | $+$ 0.00002 |
| Totals. | $-$ 1.70871 | $-$ 1.70879 | $+$ 0.00008 |

11. The perturbations thus found were applied and Elements II were carried forward to 1903 and backward to 1889; the following elements representing the appearance of 1903:

ELEMENTS II.

Epoch, 1903 September 18.5 Greenwich Mean Time.

$$\begin{aligned} \mu &= 499''.74397 \\ L &= 350^\circ\ 47'\ 41''.36 \\ \pi &= 1\ \ 45\ \ 7\ .39 \\ \Omega &= 18\ \ 6\ \ 27\ .76 \\ i &= 6\ \ 3\ \ 45\ .31 \\ \phi &= 28\ \ 1\ \ 3\ .71 \\ M_0 &= 349\ \ 2\ \ 33\ .97 \end{aligned} \left.\vphantom{\begin{aligned} L \\ \pi \\ \Omega \\ i \\ \phi \end{aligned}}\right\} 1903.0$$

With these elements an ephemeris was computed for August, September and October, 1903.

The comet was rediscovered by Aitken on August 18, 1903, at which time it was a little north following the ephemeris. With four observations, as published by Aitken, a normal place was formed for August 22.5 and the ephemeris gave the following differences in the sense observed *minus* computed.

$$\Delta\alpha = +\ 0^m\ 18^s.80$$
$$\Delta\delta = +\ 1'\ 20''.90$$

which was not as satisfactory as had been hoped. Aitken[1] reported the comet as faint and small and a most difficult object to observe; the above differences in $\alpha$ and $\delta$ are not large, therefore, being little greater than the apparent diameter of the comet itself.

The perturbations, as computed in 9, were applied to Elements II and the osculating elements representing the appearance of 1889 found. With these a partial ephemeris was computed and a normal place formed for 1889 September 18.5 and with Elements II a normal place was formed for 1896 September, 9.5. Comparing these normal places with that for 1903, as given above, I find that Elements II represent the three appearances in the following manner; the differences being given in the sense, observed *minus* computed:

| | $\cos\delta\Delta\alpha$ | $\Delta\delta$ |
|---|---|---|
| 1889 Sept. 18.5 | $+\ 7''.39$ | $+\ 5''.03$ |
| 1896 Sept. 9.5 | $-\ 0\ .96$ | $+\ 5\ .16$ |
| 1903 Aug. 22.5 | $+251\ .20$ | $+80\ .90$ |

[1] *Lick Observatory Bulletin*, No. 49.

An attempt was made to correct Elements II so as to satisfy the three appearances, but without full success; the resulting residuals being too large. To satisfy the equations representing the appearance in 1903, $\mu$ would have to be increased: such an increase, however, would throw large discordances in the normal places representing the first appearance in 1889. In other words, the mean motion of the comet during the interval 1896–1903 seemed to be greater than the mean motion during the interval 1896–1889. The two appearances of 1889 and 1896 could be brought into accord; so could the appearances of 1896 and 1903, but no value of the mean motion would at once satisfy all three appearances. It was not possible to satisfy the three appearances by any simple variation of Elements II.

This seemed to indicate an error in the computed perturbations or in some neglected perturbation. The perturbations of the four planets, Earth, Mars, Jupiter and Saturn had been carefully checked and the results agree extremely well with those obtained entirely independently by Neugebauer and referred to in 10. From the result of the comparison there given it would seem as though these perturbations were accurately computed.

The perturbations of Uranus were far too small to be of any account. It remained then to test the effect of Venus upon the comet. A computation of these perturbations for a few dates showed that they were quite as large and fully as important as those of either the Earth or Mars. Another fact which led me to attribute these discordances to the action of Venus, is that Venus was in widely different parts of her orbit at the times the comet passed perihelion in 1889 and 1896, and consequently the acceleration or retardation of the comet would be radically different in 1896–97 from what it was in 1889–90. While the comet was passing over the arc of its orbit near perihelion in 1889–90, the action of Venus was such as to retard it and to decrease its mean motion; while the comet was passing over a corresponding arc of its orbit in 1896–97, the action of Venus was such as to accelerate it and to increase its mean motion.

This is exactly the effect necessary to reconcile the discordances noted in the three appearances. Consequently, I undertook to determine by computation the effect of the perturbations of Venus upon the comet.

Owing to the rapid motion of Venus about the sun the perturbations change sign frequently and the interval of computation should be very short. The perturbations were computed for the entire interval 1889 to 1903 with a 20-day interval from January 1889 to April 1890, from April 1896 to May 1897 and from May 1903 to December 1903; these three periods being the times of closest approach of the comet to the planet. During the remaining times the comet was at such a distance from Venus that the direct action of that planet upon the comet became very small and during these periods the interval of computation was made 40 days.

The computations were carried out in a manner entirely similar to those of 9: the adopted mass of Venus being

$$\frac{1}{390,000}.$$

The values of the integrated perturbations for the intervals between the various appearances are given in the following table; the date of osculation being, 1896 October 23.5:

PERTURBATIONS BY VENUS.

| | 1896–1889. | 1896–1903. |
|---|---|---|
| $\Delta\mu$ | $+\ 0''.01095$ | $+\ 0''.00950$ |
| $\Delta\pi$ | $-\ 0.675$ | $-\ 1.885$ |
| $\Delta\Omega$ | $+\ 0.427$ | $+\ 0.215$ |
| $\Delta\phi$ | $-\ 1.607$ | $-\ 5.832$ |
| $\Delta i$ | $+\ 0.159$ | $+\ 0.344$ |
| $\Delta L_{\mathrm{I}}$ | $-\ 5.869$ | $+\ 10.703$ |
| $\Delta L_{\mathrm{II}}$ | $-\ 28.623$ | $+\ 79.160$ |

With these additional perturbations Elements II were carried back to 1889 and forward to 1903 and a normal place formed representing each of the three appearances. From these nor-

mals a correction to the mean motion, $\mu$, was found; this correction being

$$\Delta\mu = -0''.014,$$

The resulting elements represent the three appearances in a very satisfactory manner. Applying this correction to Elements II, I have for my approximate elements:

ELEMENTS III.

Epoch, 1896 October 23.5 Greenwich Mean Time.

$$\begin{array}{ll}
\mu = & 499''.9697 \\
L & 0^\circ\ 11'\ 47''.92 \\
\pi = & 1\ \ 48\ \ 53\ .69 \\
\Omega = & 18\ \ \ 1\ \ \ 7\ .76 \\
\phi = & 27\ \ 59\ \ 56\ .39 \\
i = & 6\ \ \ 3\ \ 34\ .08 \\
M_0 = & 358\ \ 22\ \ 54\ .23
\end{array}
\left.\begin{array}{l}\\ \\ \\ \\ \\ \end{array}\right\} 1896.0$$

and these elements were made the basis of all subsequent work and definitive corrections to them found from all the available observations of the first two appearances and the first few observations of the third appearance in 1903.

Applying to Elements III the perturbations, including those of Venus, I have for the osculating elements which represent the first and the third appearances:

ELEMENTS III.

Epoch, 1889 Sept. 30.5

$$\begin{array}{ll}
\mu = & 501''.68027 \\
L = & 1^\circ\ 36'\ 26''.26 \\
\pi = & 1\ \ 35\ \ \ 5\ .27 \\
\Omega = & 17\ \ 59\ \ \ 5\ .00 \\
\phi = & 28\ \ \ 5\ \ \ 9\ .41 \\
i = & 6\ \ \ 4\ \ \ 7\ .20 \\
M_0 & 0\ \ \ 1\ \ 20\ .99
\end{array}
\left.\begin{array}{l}\\ \\ \\ \\ \\ \end{array}\right\} 1890.0$$

Epoch, 1903 Sept. 18.5

$$\begin{array}{ll}
\mu = & 499''.73947 \\
L = & 350^\circ\ 48'\ 35''.95 \\
\pi = & 1\ \ 45\ \ \ 5\ .50 \\
\Omega = & 18\ \ \ 6\ \ 27\ .97 \\
\phi = & 28\ \ \ 0\ \ 57\ .88 \\
i = & 6\ \ \ 3\ \ 45\ .66 \\
M_0 = & 349\ \ \ 3\ \ 30\ .45
\end{array}
\left.\begin{array}{l}\\ \\ \\ \\ \\ \end{array}\right\} 1903.0$$

## B. *Observations of the Comet.*

*First Appearance 1889 to 1891.*

12. The comet was discovered on July 6, 1889, by William R. Brooks, at Smith Observatory, Geneva, New York, and was

observed by many observers until March 20, 1890. It was again found by Barnard, using the 36-inch telescope of the Lick Observatory, on November 22, 1890, and was observed by him during the next two months, the last observation, being obtained on January 12, 1901. The observations thus extend over a period of 556 days, and during this time the comet passed over 155 degrees of its orbit about the sun.

At the time of its discovery the comet was faint, appearing about as bright as an 11th magnitude star, with a small nucleus and a short wide tail about 10′ in length. At no time did it become a conspicuous object; at its brightest in September it was an easy object for telescopes of from 8 to 10 inches diameter, being about 10th magnitude, with a head some 4′ in diameter, and a short faint tail. By January 1890 it has become a very difficult object to observe and could be seen with the largest instruments only. At this time its brightness was less than one half that at discovery; it appeared as a fourteenth magnitude star, with a head of from one to two minutes in diameter, and a tail of about the same length. Upon the rediscovery by Barnard in November, it appeared as a weak, hazy nebulosity six or eight minutes in diameter. It was described by Barnard as the most difficult object he had ever measured. In August the comet was found to be accompanied by several companions; smaller, fainter bodies, which travelled in orbits nearly parallel to that of the main comet. It seemed as though the comet in some way had been shattered and broken up into fragments. The observations of these bodies were discussed and their orbits determined by Chandler.[1]

13. In all, some 446 complete observations were made by 46 different observers on 158 different days. The instruments with which these observations were made varied in size from 5½-inch refractor used by Schwab at Kremsmünster to the 36-inch Lick telescope used by Barnard. Most of the telescopes were fitted with filar micrometers, only five observers using ring micrometers and but two using square-bar micrometers. These

[1] "Definitive Orbits of the Companions of Comet 1889 V," *Astr. Jour.*, Nos. 236, 237.

observations were all published with full details in standard journals, easily accessible, hence only the reference need be given here. The following table, then, contains the necessary information regarding the original observations, the first column containing the name of the observatory, the second a brief description of the instrument, and the third the reference to the publication, giving volume, number and page.

TABLE II.

| Observatory. | Instrument. | Reference. |
|---|---|---|
| Algiers. | $0^m.50$ Refr. Fil. Micr. | C. R. Vol. 109, p. 433, Bull. VI, 480. |
| Baltimore. | 9.5-in. Equat. Fil. Micr. | A. J. IX, 104. |
| Berlin. | 9-in. Refr. Fil. Micr. | A. N. 124, 347. |
| Bordeaux. | 14-in. Equat. Fil. Micr. | A. N. 126, 93. |
| Cambridge, Mass. | 15-in. Equat. Fil. Micr. | A. J. IX, 69; X, 69; A. N. 122, 217; 126, 43. |
| Copenhagen. | 10.5-in. Refr. Fil. Micr. | A. N. 126, 25, 136, 306. |
| Dresden. | 12-in. Refr. Fil. Micr. | A. N. 122, 189, 301; 123, 107; 124, 29, 283. |
| Greenwich. | 6.7-in. Refr. Fil. Micr. | Monthly Not. 49, 446. |
| Hamburg. | 10-in. Refr. Fil. Micr. | A. N. 122, 189, 217; 127, 53. |
| Hanover. | 9-in. Equat. Ring Micr. | A. J. IX, 134. |
| Haverford. | 10-in. Equat. Fil. Micr. | A. J. IX, 141. |
| Kremsmünster. | 5.5-in. Refr. Ring Micr. | A. N. 124, 27. |
| Liege. | 10-in. Refr. Fil. Micr. | A. N. 126, 37. |
| Lyons. | $0^m.35$ Equat. coudé. | C. R. T. 109, 498. |
| Milan. | 8-in. Refr. Ring Micr. | A. N. 126, 137. |
| Marseilles. | $0^m.26$ Equat. Fil. Micr. | Bull. VI, 393, 519. |
| Mt. Hamilton. | 12-in. Refr. Fil. Micr. | A. J. IX, 54; X, 5. |
| Mt. Hamilton. | 36-in. Refr. Fil. Micr. | A. J. X, 111, 136; XI, 4; A. N. 126, 137, 231. |
| Munich. | 10.5-in. Refr. Fil. Micr. | A. N. 122, 189; 123, 407. |
| Nicolaeff. | 9-in. Refr. Fil. Micr. | A. N. 123, 303. |
| Nice. | $0^m.38$ Equat. Fil. Micr. | Bull. VI, 427, 522; VII, 106. C. R. T. 110, 31. |
| Padua. | $0^m.19$ Equat. Wire Micr. | A. N. 123, 361; 124, 111. |
| Palermo. | $0^m.25$ Equat. Fil. Micr. | A. N. 124, 31. |
| Paris. | $0^m.38$ Equat. Fil. Micr. | Bull. VII, 304. |
| Princeton. | 23-in. Refr. Square-bar Micr. | A. J. IX, 117, 135, 159, 191. |
| Pulkowa. | 15-in. Refr. Fil. Micr. | A. N. 124, 365; 126, 57. |
| Strassburg. | 18-in. Refr. Fil. Micr. | A. N. 124, 203. |
| Strassburg. | 6-in. Refr. Ring Micr. | A. N. 124, 371. |
| Toulouse. | 15-in. Refr. Fil. Micr. | Bull. VII, 229. |
| Vienna. | 27-in. Refr. Fil. Micr. | A. N. 125, 261, 281. |
| Vienna. | 12-in. Refr. Fil. Micr. | A. N. 125, 261. |
| Vienna. | 6-in. Refr. Ring Micr. | A. N. 125, 261. |
| Washington. | 9.6-in. Refr. Fil. Micr. | A. J. IX, 72, 93, 112, 132. |
| Washington. | 26-in. Refr. Fil. Micr. | A. J. IX, 135, 165. |
| Windsor. | 8-in. Refr. Square-bar Micr. | A. N. 123, 409. |

*Second Appearance 1896 to 1897.*

14. The comet was discovered at its return by Javelle at Nice on June 20, 1896, and was observed until February 25, 1897. The observations thus extended over a period of 250 days, during which time the comet passed over 100 degrees of its orbit about the sun. During this second appearance the comet was very faint and a most difficult object to observe. It could be observed only with the larger telescopes, and is described as being a round nebulous mass slightly less than one minute in diameter. At first it had a central nucleus, which appeared small and about the twelfth magnitude. This nucleus afterwards disappeared and the comet appeared only a small spot of haze or nebulosity. The companions were sought for, but were not seen.

In all somewhat over 100 separate and complete observations were made by 15 observers on 103 different days. It is impossible to state the exact number of observations, as one observer, Howe, at Denver, frequently made three or four separate observations during one evening, using different comparison stars for each observation; on several occasions he used as many as eight. If each and every one of such measurements be called a separate observation, then Howe alone made more than 100 observations, and the total number of observations should be increased to over 200. In most cases it was found convenient to take the mean of all such measurements made in one night and to call such mean a single observation.

15. The following table gives the necessary information in regard to original observations; the name of the observatory, the character of the instrument used and the reference to the journal where complete details can be found.

TABLE III.

| Observatory. | Instrument. | Reference. |
|---|---|---|
| Bordeaux. | 14 in. Equat. Fil. Micr. | Compt. Rend. 124, 61. |
| Charlottesville. | 26 in. Refr. Fil. Micr. | A. J. XVII, 116. |
| Cordoba. | 12 in. Equat. Fil. Micr. | A. N. 142, 355. |
| Denver. | 20 in. Refr. Fil. Micr. | A. J. XVIII, 17. |
| Mt. Hamilton. | 12 in. and 36 in. Refr. Fil. Micr. | A. J. XVI, 185; XVII, 30, 182. |
| Munich. | 10½ in. Refr. Fil. Micr. | A. N. 144, 145. |
| Nice. | $0^{m}.76$ Refr. Fil. Micr. | Bull. XIV, 139; A. N. 141, 15. |
| Northfield. | 16 in. Refr. Fil. Micr. | A. J. XVII, 16; XVIII, 4. |
| Oxford. | 10 in. Refr. Ring Micr. | Monthly Not. 57, 83. |
| Rio. | 9 in. Refr. Fil. Micr. | A. N. 142, 341; C. R. 123, 633. |
| Strassburg. | 18 in. Refr. Fil. Micr. | A. N. 143, 245. |
| Washington. | 26 in. Refr. Fil. Micr. | A. J. XVII, 55, 175. |
| Vienna. | 27 in. Refr. Fil. Micr. | A. N. 143, 49. |

*The Third Appearance 1903.*

16. The comet was rediscovered on August 18, 1903, by Aitken at Mt. Hamilton, and was observed by him until January 14, 1904, a period of 149 days, during which the comet traversed 60 degrees of its orbit. The comet was faint and small, irregular in outline, and with but feeble condensation. Its greatest diameter did not exceed three minutes of arc and at the time of its discovery its brightness about equalled that of a 14th magnitude star. Later it faded greatly and became a difficult object to measure. During the whole of this period it was invisible except with the aid of the largest telescopes.

The following table gives the references to all observations, published up to the end of April, 1904.

TABLE IV.

| Observatory. | Instrument. | References. |
|---|---|---|
| Mt. Hamilton. | 36 in Refr. Fil. Micr. | Lick Bull. No. 49. |
| Washington. | 26 in Refr. Fil. Micr. | Astr. Jour. No. 558. |

## C. *Comparison of Observed Places of the Comet with the Ephemeris.*

17. An ephemeris for the times of visibility during the three appearances, 1889 to 1903, was computed with Elements III. This ephemeris was obtained in the following manner. A daily ephemeris for the years 1889 to 1897 had previously been computed with Elements II. In the direct computations of this a four-day interval had been used, the values for the intermediate dates were found by interpolation using second order differences. This ephemeris gave the true right ascensions and declinations of the comet for Greenwich mean midnight, referred to the apparent equator and equinox of date. The corrections for aberration were not applied. With Elements III were now computed a number of places of the comet, at intervals of from 8 to 24 days, and the differences between these places and the ephemeris places, as computed with Elements II, found. These differences formed a smooth curve, from which were found by interpolation the daily corrections which it was necessary to apply to the ephemeris place, computed with Elements II, in order to find the corresponding place for Elements III.

In computing this ephemeris for the different appearances, the perturbations from the respective osculating epochs to the various dates of computation were not applied. So that, during the years 1889, 1890 and 1891, the ephemeris positions of the comet still had to be corrected by the amount of the perturbations from 1889, Sept. 30.5, to date; in the years 1896 and 1897, from 1896, Oct. 23.5, to date, and in 1903 from 1903, Sept. 18.5, to date.

18. The observed right ascensions and declinations of the comet were corrected by applying the corrections for parallax. The observations were freed from aberration by subtracting the aberration time from the times as given by the observers. These times were then reduced to Greenwich mean time and expressed in decimals of a day.

19. *Weight of Observations.* — The observations made by the various observers are of varying values; the series of observations obtained by one observer agreeing remarkably well

among themselves, while a similar series obtained by another observer will show large discrepancies among the individual observations. It was, therefore, necessary to assign weights to the observers, and an approximate idea of their weights was obtained as follows. Each observation, both in $\alpha$ and $\delta$, was compared with the ephemeris and the differences in the sense, observed *minus* computed, found. Then upon the supposition that the weights were all equal, corrections to the ephemeris were found for numerous dates. These corrections were applied to the observed differences for each observation, and thus were obtained for the series of observations of each individual observer a series of residuals which closely represented the actual errors of observation. From this series of residuals the weight was obtained by the formula

$$p = \frac{m^2(n - 1)}{[vv]}$$

where $n$ is the number of observations and $v$, $v_1$ the residuals. In applying the formula, the value of $m$, the mean error of unit weight was assumed as

For $\alpha$, $m = \pm 0^s.15$ For $\delta$, $m = \pm 1''.5$

The weights as thus determined were adhered to closely in assigning the weights to the various observations, the nearest tenth being taken in most cases.

As the comet differed radically in appearance and in ease of observation in the various appearances, the observations of each appearance were treated separately, and the weights assigned as in the table. The initials in parentheses after the name of an observatory represent the various observers.

## Table V.

Table of Weights.

| | First Appearance | | Second Appearance | | Third Appearance | |
|---|---|---|---|---|---|---|
| | $P\alpha$ | $P\delta$ | $P\alpha$ | $P\delta$ | $P\alpha$ | $P\delta$ |
| Algiers (R). | 0.4 | 0.4 | | | | |
| Algiers (S). | 1.0 | 1.0 | | | | |
| Baltimore. | 0.1 | 0.0 | | | | |
| Berlin. | 0.5 | 0.5 | | | | |
| Bordeaux (R). | 1.0 | 0.1 | | | | |
| Bordeaux (C). | 0.4 | 0.1 | | | | |
| Bordeaux (P). | 0.3 | 0.0 | 1.0 | 0.1 | | |
| Cambridge. | 0.2 | 0.3 | | | | |
| Charlottsville. | | | 0.5 | 0.5 | | |
| Copenhagen. | 0.8 | 0.6 | 0.2 | 0.2 | | |
| Cordoba. | | | 0.6 | 0.2 | | |
| Denver. | | | | | | |
| Dresden. | 0.5 | 0.4 | | | | |
| Greenwich. | 0.2 | 0.2 | | | | |
| Hamburg. | 1.0 | 1.0 | | | | |
| Hanover. | 0.2 | 0.2 | | | | |
| Haverford. | 0.0 | 0.0 | | | | |
| Kremsmünster. | 0.1 | 0.1 | | | | |
| Liege. | 0.4 | 0.4 | | | | |
| Lyons. | 0.8 | 0.9 | | | | |
| Milan. | 0.8 | 0.5 | | | | |
| Marseilles. | 0.6 | 0.2 | | | | |
| Mt. Hamilton (36). | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Mt. Hamilton (12). | | | 0.3 | 0.3 | | |
| Munich. | 1.0 | 0.6 | 0.2 | 0.1 | | |
| Nicolaeff. | 0.6 | 0.6 | | | | |
| Nice (Ch). | 1.0 | 1.0 | | | | |
| Nice (E). | 0.5 | 0.2 | | | | |
| Nice (J). | | | 0.1 | 0.6 | | |
| Northfield. | | | 0.2 | 0.0 | | |
| Oxford. | | | 0.4 | 0.4 | | |
| Padua. | 0.1 | 0.2 | | | | |
| Palmero. | 0.5 | 0.2 | | | | |
| Paris. | 0.8 | 0.8 | | | | |
| Princeton (Y). | 0.4 | 0.2 | | | | |
| Princeton (M). | 0.2 | 0.2 | | | | |
| Pulkowa. | 1.0 | 1.0 | | | | |
| Rio. | | | 0.1 | 0.2 | | |
| Strassburg (K). | 1.0 | 1.0 | 0.8 | 1.0 | | |
| Strassburg (S). | 0.1 | 0.4 | | | | |
| Toulouse. | 0.2 | 0.8 | | | | |
| Vienna (P). | 0.4 | 0.5 | 0.8 | 0.8 | | |
| Vienna (Sp). | 0.1 | 0.1 | | | | |
| Vienna (12 P). | 1.0 | 1.0 | | | | |
| Vienna (6 H). | 0.2 | 0.1 | | | | |
| Washington (F). | 0.2 | 0.2 | | | | |
| Washington (H). | 1.0 | 1.0 | 0.8 | 1.0 | 0.8 | 0.8 |
| Windsor. | 0.3 | 0.2 | | | | |

20. *Comparison Stars.*—The positions of the comparison stars were carefully redetermined by S. Alfred Mitchell while at the Yerkes Observatory. This work was carried out in a most thorough and painstaking manner, entailing a great amount of labor, as some 508 stars were determined. The positions were taken from the various catalogues in the Naval Observatory, the Johns Hopkins University, and the Yerkes Observatory, in all some 65 catalogues being used. For each star the annual precession and the secular variation were computed, using the constants of Struve and Peters, and each catalogue position was brought up to 1900.0.

The systematic corrections to each catalogue, as determined by Newcomb,[1] were applied and the weighted mean of the results taken. Wherever the catalogue places indicated proper motion, the tabular results were solved by the method of least squares and a definite determination of the proper motion made. The proper motions of some 70 stars were thus obtained.

Besides the various catalogues many numbers of the A.N. and the A.J. were consulted for meridian observations of the fainter stars. Full use was also made of the published researches of Bauschinger which appeared while this portion of my work was nearing completion. These researches contained the positions of many stars which had been reobserved by Bauschinger himself, and such positions were of the greatest value. In fact, Bauschinger's investigations are so complete and satisfactory as to make mine all but superfluous. My work was so far advanced, however, that it seemed advisable to complete it, and to avail myself of the data which appeared so opportunely.

21. Bauschinger's star places were reduced to the system of the Astronomische Gesellschaft; mine, as I have already stated, to that of Newcomb. There will, therefore, be a systematic difference in our determination of the star places, and this systematic difference will be represented by the corrections to be applied to reduce Newcomb to A.G.C., and are as follows:

[1] *Papers of the American Ephemeris*, Vol. VIII, Part II.

In Right Ascension

A.G.C. *minus* Newcomb $= -0^s.030$

In Declination

| A.G.C. *minus* Newcomb Declination. | Correction. |
|---|---|
| $+25°$ | $-0''.08$ |
| 20 | $+$ .11 |
| 15 | $-$ .14 |
| 10 | $-$ .07 |
| $+$ 5 | $-$ .13 |
| 0 | $-$ .14 |
| $-$ 5 | $-$ .29 |
| 10 | $-$ .27 |
| 15 | $-$ .26 |
| 20 | $-$ .86 |
| $-25$ | $-$ .82 |

With the positions of the comparison stars thus determined, the individual observations of the comet were re-reduced. The Greenwich mean times of observation were freed from aberration time, and the true geocentric place of the comet as referred to the equator and equinox of date found. These observed positions were directly compared with the ephemeris positions, as determined in 17, and the differences in the sense, observed *minus* computed, taken.

22. *Formation of Normal Places.*—The observations were divided into convenient groups, the line of separation between two consecutive groups being usually indicated by a break in the series of observations. For each group the mean by weight of the differences in the sense, observed *minus* computed, was found and these weighted differences, together with their weights, are given in the following table. In the table the first column gives the mean date of the group; the second column the dates of the first and last observations included in the group; the third column, the difference in right ascension with its corresponding weight; and the fourth column, the difference in declination, together with its weight.

# Table VI.

Observation *minus* Ephemeris.

| Date. | | $\Delta\alpha$ | $P\alpha$ | $\Delta\delta$ | $P\delta$ |
|---|---|---|---|---|---|
| 1889 July 28.5 | July 8<br>Aug. 7 | $-0^s.31$ | 24 | $-3''.95$ | 20 |
| Aug. 30.5 | Aug. 17<br>Sept. 6 | $-0.37$ | 64 | $-2.85$ | 45 |
| Sept. 18.5 | Sept. 14<br>Sept. 23 | $-0.35$ | 25 | $-2.18$ | 20 |
| Sept. 30.5 | Sept. 24<br>Oct. 5 | $-0.37$ | 24 | $-2.02$ | 16 |
| Oct. 16.5 | Oct. 10<br>Oct. 22 | $-0.28$ | 20 | $-1.64$ | 16 |
| Nov. 4.5 | Oct. 23<br>Nov. 18 | $-0.17$ | 39 | $-0.85$ | 25 |
| Dec. 5.5 | Nov. 19<br>Dec. 27 | $-0.08$ | 40 | $+0.45$ | 38 |
| 1890 Jan. 30.5 | Jan. 8<br>Feb. 22 | $+0.28$ | 31 | $+1.34$ | 30 |
| Mar. 13.5 | Mar. 8<br>Mar. 20 | $+0.61$ | 5 | $+0.88$ | 5 |
| Dec. 21.0 | Nov. 22<br>Jan. 12 | $+1.36$ | 5 | $-7.83$ | 5 |
| 1896 July 13.5 | July 8<br>July 20 | $-0.38$ | 8 | $-2.07$ | 10 |
| Aug. 2.5 | July 30<br>Aug. 7 | $-0.42$ | 8 | $-0.55$ | 9 |
| Aug. 14.5 | Aug. 11<br>Aug. 19 | $-0.43$ | 7 | $+0.33$ | 8 |
| Sept. 1.5 | Aug. 28<br>Sept. 3 | $-0.34$ | 10 | $+1.95$ | 8 |
| Sept. 9.5 | Sept. 4<br>Sept. 15 | $-0.35$ | 10 | $+2.35$ | 7 |
| Oct. 3.5 | Sept. 24<br>Oct. 12 | $-0.29$ | 14 | $+2.79$ | 11 |
| Nov. 2.5 | Oct. 24<br>Nov. 10 | $-0.12$ | 12 | $+3.66$ | 9 |
| Dec. 2.5 | Nov. 23<br>Dec. 10 | $+0.06$ | 19 | $+3.72$ | 16 |
| Dec. 28.5 | Dec. 22<br>Jan. 6 | $+0.14$ | 12 | $+4.12$ | 13 |
| 1897 Jan. 23.5 | Jan. 22<br>Jan. 26 | $+0.15$ | 2 | $+2.65$ | 1 |
| Feb. 4.5 | Feb. 4 | $-0.01$ | 1 | $+2.80$ | 1 |
| Feb. 24.5 | Feb. 25 | $-0.06$ | 1 | $+0.33$ | 1 |
| 1903 Aug. 22.5 | Aug. 18<br>Aug. 29 | $-0.91$ | 4 | $-1.00$ | 4 |
| Oct. 22.5 | Oct. 16<br>Oct. 24 | $-0.16$ | 4 | $+5.50$ | 4 |

Applying these differences to the ephemeris places of the comet, we have the following observed normal places, together with their adopted weights.

## TABLE VII.

### OBSERVED NORMAL PLACES.

| | Date. | | | True R. A. | Wt. | True Decl. | Wt. |
|---|---|---|---|---|---|---|---|
| | | | | h m s | | ° ′ ″ | |
| 1 | 1889 | July | 28.5 | 0 2 18.82 | 24 | − 7 16 2.0 | 20 |
| 2 | | Aug. | 30.5 | 5 45.70 | 64 | − 5 53 16.1 | 45 |
| 3 | | Sept. | 18.5 | 23 55 28.78 | 25 | − 5 29 24.5 | 20 |
| 4 | | Sept. | 30.5 | 47 53.26 | 24 | − 5 4 32.9 | 16 |
| 5 | | Oct. | 16.5 | 41 8.48 | 20 | − 4 4 35.0 | 16 |
| 6 | | Nov. | 4.5 | 42 15.01 | 39 | − 2 8 1.3 | 25 |
| 7 | | Dec. | 5.5 | 0 5 47.25 | 40 | + 2 28 40.7 | 38 |
| 8 | 1890 | Jan. | 30.5 | 1 28 42.09 | 31 | +12 46 0.5 | 30 |
| 9 | | Mar. | 13.5 | 2 45 45.30 | 5 | +19 50 55.3 | 5 |
| 10 | | Dec. | 21.0 | 8 54 11.94 | 5 | +25 25 11.2 | 5 |
| 11 | 1896 | July | 13.5 | 22 38 5.99 | 8 | −18 12 28.6 | 10 |
| 12 | | Aug. | 2.5 | 37 32.04 | 8 | −18 35 6.6 | 9 |
| 13 | | Aug. | 14.5 | 32 7.98 | 7 | −18 56 2.9 | 8 |
| 14 | | Sept. | 1.5 | 20 9.92 | 10 | −19 7 46.3 | 8 |
| 15 | | Sept. | 9.5 | 15 0.31 | 10 | −19 57 4.3 | 7 |
| 16 | | Oct. | 3.5 | 8 3.82 | 14 | −17 9 21.7 | 11 |
| 17 | | Nov. | 2.5 | 24 25.90 | 12 | −12 41 39.7 | 9 |
| 18 | | Dec. | 2.5 | 23 2 39.85 | 19 | − 6 39 41.2 | 16 |
| 19 | | Dec. | 28.5 | 45 39.48 | 12 | − 0 43 20.4 | 13 |
| 20 | 1897 | Jan. | 23.5 | 0 33 26.52 | 2 | + 5 24 45.6 | 1 |
| 21 | | Feb. | 4.5 | 56 29.66 | 1 | + 8 11 22.6 | 1 |
| 22 | | Feb. | 24.5 | 1 37 54.24 | 1 | +12 48 32.1 | 1 |
| 23 | 1903 | Aug. | 22.5 | 21 0 8.10 | 4 | −27 3 49.0 | 4 |
| 24 | | Oct. | 22.5 | 10 59.57 | 4 | −21 13 13.1 | 4 |

23. *Perturbations.*—The perturbations as computed in 9 were reintegrated for the period of visibility of each appearance, making the respective osculating epochs, 1889 Sept. 30.5, 1896 Oct. 23.5, and 1903 Sept. 18.5 for which dates the elements used in computing the ephemeris are osculating. From the new tables thus formed were found by interpolation the perturbations of the elements for the dates of normal places. These perturbations of the elements were then transformed into the corresponding perturbations of right ascension and declination by means of the coefficients of the equations of condition, as determined in 24. In using these coefficients it was necessary to recompute those

involving $(t-T_0)$, making $T_0$ respectively 1889 Sept. 30.5 for all dates in the first appearance, and 1903 Sept. 18.5 for all dates in the third appearance. Thus were obtained:

## Table VIII.

Perturbations in R. A. and Decl.

| | | | | $\cos\delta\,\Delta\alpha''$ | $\Delta\delta''$ |
|---|---|---|---|---|---|
| | | | | $''$ | $''$ |
| 1 | 1889 | July | 28.5 | −0.42 | −0.23 |
| 2 | | Aug. | 30.5 | − .34 | + .06 |
| 3 | | Sept. | 18.5 | − .14 | − .06 |
| 4 | | Sept. | 30.5 | .0 | .0 |
| 5 | | Oct. | 16.5 | .0 | + .02 |
| 6 | | Nov. | 4.5 | + .03 | + .04 |
| 7 | | Dec. | 5.5 | + .11 | + .14 |
| 8 | 1890 | Jan. | 30.5 | +1.17 | + .55 |
| 9 | | Mar. | 13.5 | +2.96 | + .62 |
| 10 | | Dec. | 21.0 | +8.92 | −6.08 |
| | | | | | |
| 11 | 1896 | July | 13.5 | −1.09 | −1.21 |
| 12 | | Aug. | 2.5 | −0.80 | +0.54 |
| 13 | | Aug. | 14.5 | − .56 | + .47 |
| 14 | | Sept. | 1.5 | − .20 | + .24 |
| 15 | | Sept. | 9.5 | .16 | + .06 |
| 16 | | Oct. | 3.5 | − .06 | + .36 |
| 17 | | Nov. | 2.5 | − .34 | + .65 |
| 18 | | Dec. | 2.5 | − .05 | .0 |
| 19 | | Dec. | 28.5 | − .12 | + .05 |
| 20 | 1897 | Jan. | 23.5 | − .91 | − .48 |
| 21 | | Feb. | 4.5 | −2.64 | − .36 |
| 22 | | Feb. | 24.5 | −4.73 | −2.40 |
| | | | | | |
| 23 | 1903 | Aug. | 22.5 | −9.73 | −3.10 |
| 24 | | Oct. | 22.5 | +1.15 | −0.55 |

Subtracting these perturbations from the differences for corresponding dates, as given in Table VI, I have for the final differences between observation and theory, the following:

## Table IX.

Observation *minus* Computation.

| | | | $\Delta\alpha$ | *Wt.* | $\Delta\delta$ | *Wt.* |
|---|---|---|---|---|---|---|
| | | | ″ | | ″ | |
| 1889 | July | 28.5 | −4.30 | 24 | −3.72 | 20 |
| | Aug. | 30.5 | −5.11 | 64 | −2.91 | 45 |
| | Sept. | 18.5 | −5.02 | 25 | −2.12 | 20 |
| | Sept. | 30.5 | −5.51 | 24 | −2.02 | 16 |
| | Oct. | 16.5 | −4.17 | 20 | −1.66 | 16 |
| | Nov. | 4.5 | −2.63 | 39 | −0.89 | 25 |
| | Dec. | 5.5 | −1.30 | 40 | +0.31 | 38 |
| 1890 | Jan. | 30.5 | +2.96 | 31 | +0.79 | 30 |
| | Mar. | 13.5 | +5.70 | 5 | +0.26 | 5 |
| | Dec. | 21.5 | +9.44 | 5 | −1.75 | 5 |
| 1896 | July | 13.5 | −4.25 | 8 | −0.86 | 10 |
| | Aug. | 2.5 | −5.11 | 8 | −1.09 | 9 |
| | Aug. | 14.5 | −5.47 | 7 | −0.14 | 8 |
| | Sept. | 1.5 | −4.99 | 10 | +1.71 | 8 |
| | Sept. | 9.5 | −4.83 | 10 | +2.29 | 7 |
| | Oct. | 3.5 | −4.18 | 14 | +2.43 | 11 |
| | Nov. | 2.5 | −1.34 | 12 | +3.01 | 9 |
| | Dec. | 2.5 | +1.01 | 19 | +3.72 | 16 |
| | Dec. | 28.5 | +2.24 | 12 | +4.07 | 13 |
| 1897 | Jan. | 23.5 | +3.09 | 2 | +3.13 | 1 |
| | Feb. | 4.5 | +2.48 | 1 | +3.16 | 1 |
| | Feb. | 24.5 | +3.92 | 1 | +2.73 | 1 |
| 1903 | Aug. | 22.5 | −2.42 | 4 | +2.10 | 4 |
| | Oct. | 22.5 | −3.38 | 4 | −4.95 | 4 |

### D. *Definitive Correction to the Elements.*

24. The differential coefficients for the variation of the elements were computed; the elements being referred to the mean equator and equinox of 1896.0, and 1896 Oct. 23.5 being the epoch for which the elements are osculating. Each normal place is represented by two equations; one in right ascension and one in declination, the known terms in each being the difference between observation and computation, as given in Table IX. There are, therefore, forty-eight equations in all, of which the first twenty represent the first appearance, 1889–91, the next twenty-four the second appearance, 1896–97, and the last four the third appearance in 1903. In the group of equations which represent each appearance the right ascension and the declination equations are grouped together in subgroups, the right ascension group being given first in each case. In these equations the coefficients are logarithms.

# Table X.

## Equations of Condition.

| $\Delta\pi$ | $\Delta\Omega$ | $\Delta i$ | $\Delta\phi$ | $\Delta M_0$ | $\Delta\mu$ | $n$ | Wght. |
|---|---|---|---|---|---|---|---|
| 0.11177 | 8.76343 | 9.74359 | 9.87442$_n$ | 0.60893 | 4.11957$_n$ | 0.63347 | 24 |
| 0.22523 | 8.97589 | 9.68368 | 9.68619$_n$ | 0.71767 | 4.13670$_n$ | 0.70842 | 64 |
| 0.25387 | 8.97635 | 9.56620 | 9.57990$_n$ | 0.75097 | 4.16466$_n$ | 0.70070 | 25 |
| 0.24588 | 8.97955 | 9.44201 | 9.48615$_n$ | 0.74425 | 4.15742$_n$ | 0.74115 | 24 |
| 0.20669 | 8.96379 | 9.17260 | 9.18696$_n$ | 0.70697 | 4.12031$_n$ | 0.62014 | 20 |
| 0.13523 | 8.91751 | 8.47567 | 8.89763 | 0.64324 | 4.05091$_n$ | 0.41996 | 39 |
| 0.01528 | 8.81690 | 9.11528$_n$ | 9.71784 | 0.52088 | 3.92508$_n$ | 0.11394 | 40 |
| 9.88750 | 8.57749 | 9.38810$_n$ | 0.06145 | 0.34138 | 3.65338$_n$ | 0.47129$_n$ | 31 |
| 9.85763 | 8.32015 | 9.36474$_n$ | 0.16435 | 0.23502 | 3.63038$_n$ | 0.75588$_n$ | 5 |
| 0.07904 | 8.42160 | 9.59561 | 0.31418 | 9.98507 | 3.30211$_n$ | 0.97497$_n$ | 5 |
| 9.89631 | 9.05423$_n$ | 9.99383$_n$ | 9.84671$_n$ | 0.37972 | 3.89555$_n$ | 0.57054 | 20 |
| 9.98865 | 9.20058$_n$ | 9.93394$_n$ | 9.73070$_n$ | 0.48015 | 3.89732$_n$ | 0.46389 | 45 |
| 0.00398 | 9.25406$_n$ | 9.81908$_n$ | 9.57310$_n$ | 0.49679 | 3.91497$_n$ | 0.32634 | 20 |
| 9.99572 | 9.26552$_n$ | 9.69671$_n$ | 9.38471$_n$ | 0.49407 | 3.90787$_n$ | 0.30535 | 16 |
| 9.96118 | 9.24601$_n$ | 9.43008$_n$ | 8.67117$_n$ | 0.45176 | 3.87393$_n$ | 0.22011 | 16 |
| 9.89823 | 9.19948$_n$ | 8.73239$_n$ | 9.20602 | 0.39707 | 3.80960$_n$ | 9.94939 | 25 |
| 9.79449 | 9.09132$_n$ | 9.36642 | 9.65524 | 0.28679 | 3.69134$_n$ | 9.49136$_n$ | 38 |
| 9.62859 | 8.88986$_n$ | 9.67173 | 9.83104 | 0.06845 | 3.37618$_n$ | 9.89763$_n$ | 30 |
| 9.48869 | 8.74508$_n$ | 9.74772 | 9.79309 | 9.85193 | 3.25410$_n$ | 9.41497$_n$ | 5 |
| 9.60541$_n$ | 8.40993 | 0.10120 | 9.85248$_n$ | 9.54058$_n$ | 2.86589 | 0.24304 | 5 |
| 0.14180 | 8.45209 | 9.81407 | 0.32150$_n$ | 0.58789 | 2.40391$_n$ | 0.62839 | 8 |
| 0.20690 | 8.60938 | 9.82788 | 0.35418$_n$ | 0.66074 | 2.43779$_n$ | 0.70842 | 8 |
| 0.23515 | 8.63796 | 9.81666 | 0.37045$_n$ | 0.69200 | 2.45896$_n$ | 0.73799 | 7 |
| 0.24781 | 8.73806 | 9.76062 | 0.37323$_n$ | 0.70929 | 2.47170$_n$ | 0.69810 | 10 |
| 0.23991 | 8.75243 | 9.72168 | 0.36162$_n$ | 0.70412 | 2.46432$_n$ | 0.68395 | 10 |
| 0.17484 | 8.76492 | 9.55960 | 0.27032$_n$ | 0.65107 | 2.38051$_n$ | 0.62118 | 14 |
| 0.05722 | 8.75359 | 9.25972 | 0.03400$_n$ | 0.55273 | 2.13472$_n$ | 0.12710 | 12 |
| 9.95360 | 8.72495 | 8.57628 | 9.54337$_n$ | 0.46144 | 1.53807$_n$ | 0.00432$_n$ | 19 |
| 9.88992 | 8.67929 | 8.78611$_n$ | 9.23716 | 0.39506 | 1.60152 | 0.35025$_n$ | 12 |
| 9.85035 | 8.60959 | 9.12545$_n$ | 9.77332 | 0.33836 | 2.00663 | 0.48996$_n$ | 2 |
| 9.83912 | 8.56995 | 9.19698$_n$ | 9.87944 | 0.31468 | 2.10119 | 0.39445$_n$ | 1 |
| 9.82812 | 8.48054 | 9.26613$_n$ | 0.00249 | 0.27603 | 2.21680 | 0.59329$_n$ | 1 |
| 9.86879 | 8.88250$_n$ | 0.11109$_n$ | 0.18254$_n$ | 0.29241 | 2.22680$_n$ | 9.93450 | 10 |
| 9.92232 | 9.01769$_n$ | 0.12947$_n$ | 0.14407$_n$ | 0.35628 | 2.26384$_n$ | 0.03743 | 9 |
| 9.93441 | 9.08170$_n$ | 0.12344$_n$ | 0.14734$_n$ | 0.37432 | 2.26949$_n$ | 9.14613 | 8 |
| 9.91825 | 9.14775$_n$ | 0.08362$_n$ | 0.11492$_n$ | 0.36859 | 2.23926$_n$ | 0.23300$_n$ | 8 |
| 9.89991 | 9.16474$_n$ | 0.05179$_n$ | 0.08488$_n$ | 0.35583 | 2.20966$_n$ | 0.35984$_n$ | 7 |
| 9.82976 | 9.17465$_n$ | 9.89996$_n$ | 9.94350$_n$ | 0.30485 | 2.05918$_n$ | 0.38561$_n$ | 11 |
| 9.75631 | 9.12875$_n$ | 9.57820$_n$ | 9.65234$_n$ | 0.25199 | 1.72449$_n$ | 0.47857$_n$ | 9 |
| 9.70385 | 9.05464$_n$ | 8.85378$_n$ | 8.84128$_n$ | 0.20721 | 0.20112 | 0.57054$_n$ | 16 |
| 9.66292 | 8.98419$_n$ | 9.04155 | 9.31738 | 0.15995 | 1.61634 | 0.60959$_n$ | 13 |
| 9.61879 | 8.91499$_n$ | 9.37809 | 9.61836 | 0.09754 | 1.85244 | 0.49554$_n$ | 1 |
| 9.59586 | 8.88431$_n$ | 9.45719 | 9.68387 | 0.06252 | 1.90835 | 0.49969$_n$ | 1 |
| 9.54969 | 8.83264$_n$ | 9.55448 | 9.74470 | 9.99052 | 1.96171 | 0.43616$_n$ | 1 |
| 0.23522 | 8.33883 | 9.70674 | 0.52927$_n$ | 0.63876 | 4.03294 | 0.38382 | 4 |
| 0.04336 | 8.51701 | 9.42375 | 0.29130$_n$ | 0.49782 | 3.89584 | 0.52892 | 4 |
| 9.75213 | 8.97933$_n$ | 0.17406$_n$ | 0.10092$_n$ | 0.12909 | 3.51824 | 0.32222$_n$ | 4 |
| 9.60942 | 9.04411$_n$ | 9.86704$_n$ | 9.83773$_n$ | 0.06640 | 3.46532 | 0.69460$_n$ | 4 |

These equations were multiplied by the square root of their respective weights and for convenience the following auxiliary unknowns were substituted.

$$
\begin{aligned}
x &= [1.10]\ \Delta\pi \\
y &= \phantom{[1.10]}\ \Delta\Omega \\
z &= [0.80]\ \Delta i \\
t &= [1.10]\ \Delta\phi \\
u &= [1.60]\ \Delta M_0 \\
v &= [5.00]\ \Delta\mu \\
n' &= [1.80]\ n
\end{aligned}
$$

in which the quantities in brackets are logarithms. This substitution resulted in the following, in which all the coefficients are logarithms.

# Table XI.

## Equations of Equal Weight.

| $x$ | $y$ | $z$ | $t$ | $u$ | $v$ | $n'$ |
|---|---|---|---|---|---|---|
| 9.70188 | 9.45354 | 9.63370 | $9.46453_n$ | 9.69904 | $9.80968_n$ | 9.52358 |
| 0.02832 | 9.87898 | 9.78677 | $9.48928_n$ | 0.02076 | $0.03979_n$ | 9.81151 |
| 9.85284 | 9.67532 | 9.46517 | $9.17887_n$ | 9.84994 | $9.86363_n$ | 9.59967 |
| 9.83599 | 9.66966 | 9.33212 | $9.07626_n$ | 9.83436 | $9.84753_n$ | 9.63126 |
| 9.75721 | 9.61431 | 9.02312 | $8.73748_n$ | 9.75749 | $9.77083_n$ | 9.47066 |
| 9.83076 | 9.71304 | 8.47120 | 8.59316 | 9.83877 | $9.84644_n$ | 9.41549 |
| 9.71631 | 9.61793 | $9.11631_n$ | 9.41887 | 9.72191 | $9.72611_n$ | 9.11497 |
| 9.53318 | 9.32317 | $9.33378_n$ | 9.70713 | 9.48706 | $9.39906_n$ | $9.41697_n$ |
| 9.10711 | 8.66963 | $8.91422_n$ | 9.41383 | 8.98450 | $8.97986_n$ | $9.30536_n$ |
| 9.32852 | 8.77108 | 9.14509 | 9.56366 | 8.73455 | $8.65159_n$ | $9.52445_n$ |
| | | | | | | |
| 9.44683 | $9.70475_n$ | $9.84435_n$ | $9.39723_n$ | 9.43024 | $9.54607_n$ | 9.42106 |
| 9.71526 | $0.02719_n$ | $9.96055_n$ | $9.45731_n$ | 9.70676 | $9.72393_n$ | 9.49050 |
| 9.55450 | $9.90458_n$ | $9.66960_n$ | $9.12362_n$ | 9.54731 | $9.56549_n$ | 9.17686 |
| 9.49778 | $9.86758_n$ | $9.49877_n$ | $8.88677_n$ | 9.49613 | $6.50993_n$ | 9.10741 |
| 9.46324 | $9.84807_n$ | $9.23214_n$ | $8.17323_n$ | 9.45382 | $9.47599_n$ | 9.02217 |
| 9.49720 | $9.89845_n$ | $8.63136_n$ | 8.80499 | 9.49604 | $9.50857_n$ | 8.84836 |
| 9.48438 | $9.88121_n$ | 9.35631 | 9.34513 | 9.47668 | $9.48123_n$ | $8.48125_n$ |
| 9.26715 | $9.62842_n$ | 9.61029 | 9.46960 | 9.20701 | $9.11474_n$ | $8.83619_n$ |
| 8.73817 | $9.09456_n$ | 9.29720 | 9.04257 | 8.60141 | $8.60358_n$ | $7.96445_n$ |
| $8.85489_n$ | 8.75941 | 9.65068 | $9.10196_n$ | $8.29006_n$ | 8.21537 | 8.79252 |
| | | | | | | |
| 9.49334 | 8.90363 | 9.46561 | $9.67304_n$ | 9.43943 | $7.85545_n$ | 9.27993 |
| 9.55844 | 9.06092 | 9.47942 | $9.70572_n$ | 9.51228 | $7.88933_n$ | 9.35996 |
| 9.55770 | 9.06051 | 9.43921 | $9.69300_n$ | 9.51455 | $7.88151_n$ | 9.36054 |
| 9.64781 | 9.23806 | 9.46062 | $9.77323_n$ | 9.60929 | $7.97170_n$ | 9.39810 |
| 9.63991 | 9.25243 | 9.42168 | $9.76162_n$ | 9.60412 | $7.96432_n$ | 9.38395 |
| 9.64790 | 9.33798 | 9.33266 | $9.74338_n$ | 9.62413 | $7.95357_n$ | 93.9424 |
| 9.49681 | 9.29318 | 8.99931 | $9.47359_n$ | 9.49232 | $7.67431_n$ | 8.86669 |
| 9.49298 | 9.36433 | 8.41566 | $9.08275_n$ | 9.50082 | $7.17745_n$ | $8.84370_n$ |
| 9.32951 | 9.21888 | $8.52570_n$ | 8.67675 | 9.33465 | 7.14111 | $9.08984_n$ |
| 8.90087 | 8.76011 | $8.47597_n$ | 8.82384 | 8.88888 | 7.15715 | $8.84048_n$ |
| 8.73912 | 8.56995 | $8.39698_n$ | 8.77944 | 8.71468 | 7.10119 | $8.59445_n$ |
| 8.72812 | 8.48054 | $8.46613_n$ | 8.90249 | 8.67603 | 7.21680 | $8.79329_n$ |
| | | | | | | |
| 9.26879 | $9.38250_n$ | $9.81109_n$ | $9.58254_n$ | 9.19241 | $7.72680_n$ | 8.63450 |
| 9.29944 | $9.49481_n$ | $9.80659_n$ | $9.52119_n$ | 9.23340 | $7.74096_n$ | 8.71455 |
| 9.28595 | $9.53324_n$ | $9.77498_n$ | $9.49888_n$ | 9.22586 | $7.72103_n$ | 7.79767 |
| 9.26979 | $9.59929_u$ | $9.73516_n$ | $9.46646_n$ | 9.22013 | $7.69080_n$ | $8.88454_n$ |
| 9.22246 | $9.58729_n$ | $9.67434_n$ | $9.40743_n$ | 9.17838 | $7.63221_n$ | $8.98239_n$ |
| 9.25046 | $9.69535_n$ | $9.62066_n$ | $9.36420_n$ | 9.22555 | $7.57988_n$ | $9.10631_n$ |
| 9.13343 | $9.60587_n$ | $9.25532_n$ | $9.02946_n$ | 9.12911 | $7.20161_n$ | $9.15569_n$ |
| 9.20591 | $9.65670_n$ | $8.65784_n$ | $8.34334_n$ | 9.20927 | 5.80318 | $9.37260_n$ |
| 9.11989 | $9.54116_n$ | 8.79852 | 8.77435 | 9.11692 | 7.17331 | $9.36656_n$ |
| 8.51879 | $8.91499_n$ | 8.57809 | 8.51836 | 8.49754 | 6.85244 | $8.69554_n$ |
| 8.49586 | $8.88431_n$ | 8.65719 | 8.58387 | 8.46252 | 6.90835 | $8.69969_n$ |
| 8.44969 | $8.83264_n$ | 8.75448 | 8.64471 | 8.39052 | 6.96171 | $8.63616_n$ |
| | | | | | | |
| 9.43625 | 8.63986 | 9.20777 | $9.73030_n$ | 9.33979 | 9.33397 | 8.88485 |
| 9.24439 | 8.81804 | 8.92478 | $9.49233_n$ | 9.19885 | 9.19687 | 9.02995 |
| | | | | | | |
| 8.95316 | $9.28036_n$ | $9.67509_n$ | $9.30195_n$ | 8.83012 | 8.81927 | $8.82325_n$ |
| 8.81045 | $9.34514_n$ | $9.36807_n$ | $9.03876_n$ | 8.76743 | 8.76635 | $9.19563_n$ |

Treating these equations by the method of least squares, making use of the usual checks upon the computation, the following normal equations are found, in which the coefficients are numbers :

NORMAL EQUATIONS.

| $x$ | $y$ | $z$ | $t$ | $u$ | $v$ | |
|---|---|---|---|---|---|---|
| 6.082452 | +0.456189 | +0.336503 | —2.334170 | +5.872832 | —4.540830 | +2.430941=0 |
| | 7.926364 | +4.160742 | +0.171294 | +0.495343 | —0.540870 | +1.044635=0 |
| | | 5.619482 | +0.307813 | +0.360771 | —0.318383 | +0.765504=0 |
| | | | 3.939279 | —2.230876 | +0.456194 | —1.682773=0 |
| | | | | 5.708964 | —4.501701 | +2.437035=0 |
| | | | | | 4.874328 | —2.224427=0 |

The solution of these equations gave,

$$
\begin{aligned}
x &= +\,0.581967 \\
y &= -\,0.060045 \\
z &= -\,0.104155 \\
u &= -\,0.182641 \\
v &= +\,0.761030 \\
t &= +\,0.591200
\end{aligned}
$$

Whence were obtained :

$$
\begin{aligned}
\Delta\pi &= +\,2''.917 && \pm\,1''.549 \\
\Delta\Omega &= -\,3\ .789 && \pm\,0\ .452 \\
\Delta i &= -\,1\ .042 && \pm\,0\ .220 \\
\Delta\phi &= +\,2\ .963 && \pm\,0\ .216 \\
\Delta M_0 &= -\,0\ .289 && \pm\,0\ .987 \\
\Delta\mu &= +\,0\ .000480 && \pm\,0\ .0041
\end{aligned}
$$

The remaining errors are :

## Table XII.

Observation *minus* Computation.

| Date. | | | $\cos\delta\,\Delta\alpha$ | *Wt.* | $\Delta\delta$ | *Wt.* |
|---|---|---|---|---|---|---|
| | | | $''$ | | $''$ | |
| 1889 | July | 28.5 | +2.44 | 24 | —0.92 | 20 |
| | Aug. | 30.5 | +0.38 | 64 | —0.99 | 45 |
| | Sept. | 18.5 | +0.26 | 25 | —0.46 | 20 |
| | Sept. | 30.5 | —0.58 | 24 | —0.62 | 16 |
| | Oct. | 16.5 | —0.10 | 20 | —0.72 | 16 |
| | Nov. | 4.5 | +0.17 | 39 | —0.51 | 25 |
| | Dec. | 5.5 | —0.75 | 40 | —0.15 | 38 |
| 1890 | Jan. | 30.5 | —0.02 | 31 | —0.78 | 30 |
| | Mar. | 13.5 | +1.66 | 5 | —1.04 | 5 |
| | Dec. | 21.5 | +1.59 | 5 | +2.49 | 5 |
| 1896 | July | 13.5 | —0.05 | 8 | +0.51 | 10 |
| | Aug. | 2.5 | —0.80 | 8 | —0.45 | 9 |
| | Aug. | 14.5 | —1.12 | 7 | +0.44 | 8 |
| | Sept. | 1.5 | —0.72 | 10 | +2.12 | 8 |
| | Sept. | 9.5 | —0.72 | 10 | +2.58 | 7 |
| | Oct. | 3.5 | —1.01 | 14 | +2.31 | 11 |
| | Nov. | 2.5 | +0.04 | 12 | +2.32 | 9 |
| | Dec. | 2.5 | —0.48 | 19 | +2.41 | 16 |
| | Dec. | 28.5 | +0.28 | 12 | +2.26 | 13 |
| 1897 | Jan. | 23.5 | —0.14 | 2 | +0.95 | 1 |
| | Feb. | 4.5 | —1.27 | 1 | +0.88 | 1 |
| | Feb. | 24.5 | —0.63 | 1 | +0.40 | 1 |
| 1903 | Aug. | 22.5 | —0.72 | 4 | +1.08 | 4 |
| | Oct. | 22.5 | —3.27 | 4 | +3.55 | 4 |

25. The corrected elements represent the observations considerably better than Bauschinger's. The residuals, however, still show the systematic character which was mentioned in 7. The differences in right ascension are all small and the signs are irregular, but the differences in declination are larger and the signs of the terms show a systematic arrangement. With the exception of the last normal all the differences in declination of the first appearance are negative, while in the second appearance, with the exception of the second, they are all positive. The large difference in declination, $+\ 2''.49$, obtained for December 21, 1890, is completely accounted for by the fact that the normal place rests on but five discordant observations, one of which differs by more than $10''$ from the mean of the other four.

Taking the mean by weights of the differences, both in $\alpha$ and $\delta$, for each appearance I have,

| | Cos $\delta\,\Delta\alpha$ | Wt. | $\Delta\delta$ | Wt. |
|---|---|---|---|---|
| 1st appearance, | $+0^s.016$ | 277 | $-0''.58$ | 220 |
| 2nd appearance, | $-0\ .033$ | 104 | $+1\ .66$ | 95 |
| 3rd appearance, | $-0\ .133$ | 8 | $+2\ .32$ | 8 |

These differences in declination would indicate that the point of the comet, which was used in measuring its position, was a little to the south in the first appearance and a little to the north in the second appearance of the mean position as indicated by a least square solution of all the observations. Apparently the observed nucleus was a little more than $2''$ farther north than, by theory, it should have been in the second appearance. A large portion of this discrepancy, however, can be accounted for by a simple investigation of the observations upon which this determination rests and of the method of weighting such observations.

If the observations be compared with the corrected ephemeris and the differences between the observed and computed places for each separate observation formed, it will be found that the observations of each observer are affected by a systematic error. The observers at Denver and Cordoba invariably placed the comet a little north of the place assigned by the observers at Mt. Hamilton and Washington. The mean of 34 observations made with the 36-inch at Mt. Hamilton differs from the ephemeris place by $-0''.9$, while the mean of 12 observations made at Cordoba differs from the ephemeris by $+4''.3$, and the mean of 47 observations at Denver differs by $+2''.4$. Further, in the case of the Mt. Hamilton observations the individual differences are somewhat equally divided as to sign, 15 being positive and 19 negative; of the Cordoba observations, on the other hand, 11 are positive aud only 1 is negative. Thus at Cordoba the comet was always estimated as about $5''$ north and at Denver about $3''$ north of the position assigned to it by the observers at Mt. Hamilton.

Although the observations at Denver and Cordoba were given much less weight than those of Mt. Hamilton, yet it is evident that a normal place depending entirely on Denver observations would place the comet some $3''$ north of a normal place depending upon Mt. Hamilton observations solely; and a

normal made up of observations from Denver and Mt. Hamilton will place the comet at some point between these limits according as to whether the Mt. Hamilton or Denver observations predominate. The six normals which show large residuals in the above solution depend to a large extent (20 to 30 per cent.) upon Denver and Cordoba observations; the five normals which show small residuals of different signs, do not contain a single observation from either of these two observatories. Thus it is safe to conclude that the large residuals are due to systematic errors made by the different observers.

It would not be difficult to determine the personal equation of each observer and to correct the individual observations for such errors, and to reduce all the observations to a standard system, but such a proceeding would have the effect of reducing the residuals without changing the elements.

The large residuals of the third appearance are accounted for by the fact that the comet was extremely difficult to observe and the fact that the observations upon which the normal places rest are discordant among themselves; the different observations varying several seconds.

26. Applying the above determined corrections to Elements III, I have as my definitive elements the following:

ELEMENTS IV.

Epoch 1896 Oct. 23.5. Greenwich Mean Time.

| | | | | |
|---|---|---|---|---|
| $\mu =$ | $499''.97018$ | | | |
| $L =$ | $0°$ | $11'$ | $50''.55$ | 1896.0 |
| $\pi =$ | 1 | 48 | 56 .61 | 1896.0 |
| $\Omega =$ | 18 | 1 | 3 .97 | 1896.0 |
| $\varphi =$ | 27 | 59 | 59 .35 | 1896.0 |
| $i =$ | 6 | 3 | 33 .04 | 1896.0 |
| $M_0 =$ | 358 | 22 | 53 .94 | |

Epoch 1889 Sept. 30.5

| | | | | |
|---|---|---|---|---|
| $\mu =$ | $501''.68075$ | | | |
| $L =$ | $1°$ | $36'$ | $27''.66$ | 1890.0 |
| $\pi =$ | 1 | 35 | 8 .19 | 1890.0 |
| $\Omega =$ | 17 | 59 | 1 .21 | 1890.0 |
| $\varphi$ | 28 | 5 | 12 .37 | 1890.0 |
| $i =$ | 6 | 4 | 6 .16 | 1890.0 |
| $M_0 =$ | 0 | 1 | 19 .46 | |

Epoch 1903 Sept. 18.5.

| | | | | |
|---|---|---|---|---|
| $\mu =$ | $499''.73995$ | | | |
| $L =$ | $350°$ | $48'$ | $39''.78$ | 1903.0 |
| $\pi =$ | 1 | 45 | 8 .42 | 1903.0 |
| $\Omega =$ | 18 | 6 | 24 .18 | 1903.0 |
| $\varphi =$ | 28 | 1 | 0 .84 | 1903.0 |
| $i =$ | 6 | 3 | 44 .62 | 1903.0 |
| $M_0 =$ | 349 | 3 | 31 .36 | |

27. In order to determine the set of elements which best represents the motion of the comet at the time of discovery in 1889, I compared the above elements with those of Bauschinger as determined from the first appearance. The differences, in the sense observed *minus* computed, for the two sets of elements are given in the following table, for the dates of the ten normal places used in my computations.

OBSERVED *minus* COMPUTED.

| Date. | $\Delta\alpha$ | | | $\Delta\delta$ | | |
|---|---|---|---|---|---|---|
| | Poor. | $B_1$ | *Wt.* | Poor. | $B_1$ | *Wt.* |
| | s | s | | ″ | ″ | |
| 1889 July 28.5 | +0.16 | +0.14 | 24 | —0.4 | —0.6 | 20 |
| Aug. 30.5 | +0.02 | —0.03 | 64 | —1.0 | +0.1 | 45 |
| Sept. 18.5 | +0.01 | —0.02 | 25 | —0.4 | +0.6 | 20 |
| Sept. 30.5 | —0.04 | —0.04 | 24 | —0.6 | +0.3 | 16 |
| Oct. 16.5 | —0.01 | +0.02 | 20 | —0.7 | +0.3 | 16 |
| Nov. 4.5 | +0.01 | —0.04 | 39 | —0.5 | 0.0 | 25 |
| Dec. 5.5 | —0.05 | —0.04 | 40 | —0.2 | +0.2 | 38 |
| 1890 Jan. 30.5 | 0.00 | 0.00 | 31 | —0.8 | —0.1 | 30 |
| Mar. 13.5 | +0.11 | +0.33 | 5 | —1.0 | —1.7 | 5 |
| Dec. 21.5 | +0.11 | +0.02 | 5 | +2.5 | +2.5 | 5 |

Giving the above differences the weights used in my computation, I find for the sum of the squares of the weighted residuals

| | $p\Delta\Delta$ |
|---|---|
| Poor, | 333″.1 |
| Bauschinger, | 348 .9 |

These show that, so far as the first appearance only is concerned, there is very little choice between the two sets of elements. When we consider the three appearances, however, the elements, as above given, represent the comet's motion far better than those of Bauschinger. I have, therefore, adopted Elements IV, and have made them the basis of my further investigations. But in order to take account of the very slight differences between these elements and to show at a glance our knowledge of the movements of this body, I solved the equations representing the first appearance anew and expressed the elements in terms of an indeterminate quantity.

From the elimination equations derived in the solution, I have,

$$\begin{aligned}
\iota &= [0.39772\ ] + [9.36493^n]\,y \\
\omega &= [8.71081_n] + [8.00681_n]\,y \\
\varpi &= [8.61001_n] + [7.98091\ ]\,y \\
z &= [0.40361_n] + [9.42686\ ]\,y \\
x &= [8.90696_n] + [9.98806\ ]\,y
\end{aligned}$$

From these, by substituting the values of $x$, $y$, $z$, in terms of $\Delta\pi$, $\Delta\Omega$, $\Delta i$, etc., I find,

$$\begin{aligned}
\Delta\mu &= \text{constant} + 0''.011399\Delta M_0 \\
\Delta\phi &= \quad\text{"}\quad - 1\ .396130\Delta M_0 \\
\Delta\iota &= \quad\text{"}\quad\quad 0\ .113953\Delta M_0 \\
\Delta\Omega &= \quad\text{"}\quad - 0\ .017366\Delta M_0 \\
\Delta\omega &= \quad\text{"}\quad - 3\ .059290\Delta M_0
\end{aligned}$$

Now put,

$$\Delta M_0 = \text{constant} + 1''.0\ \nu$$

where $\nu$ is any number, positive, negative or fractional. Substituting the above value of $\Delta M_0$ in the expressions for the corrections to the elements, I have for that portion of the corrections which depend upon $\nu$, the following:

$$\begin{aligned}
\Delta\mu &= +0''.0114\nu \\
\Delta\phi &= -1\ .3961\nu \\
\Delta\iota &= -0\ .1140\nu \\
\Delta\Omega &= -0\ .0174\nu \\
\Delta\omega &= -3\ .0593\nu
\end{aligned}$$

Applying these corrections to Elements IV, as given in 26, they take the indeterminate and definitive form:

ELEMENTS V.

Epoch 1889 Sept. 30.5. Greenwich Mean Time.

$$\begin{aligned}
\mu &= 501''.68075 + 0''.0114\nu \\
L &= 1^\circ\ 36'\ 27''.66 - 2\ .0767\nu \\
\pi &= 1\ \ 35\ \ 8\ .19 - 3\ .0767\nu \\
\Omega &= 17\ \ 59\ \ 1\ .21 - 0\ .0174\nu \\
\varphi &= 28\ \ 5\ \ 12\ .37 - 1\ .3961\nu \\
i &= 6\ \ 4\ \ 6\ .16 - 0\ .1140\nu \\
M_0 &= 0\ \ 1\ \ 19\ .46 + 1\ .0\nu
\end{aligned}
\quad \left.\begin{matrix}L\\ \pi\\ \Omega\\ \varphi\\ i\end{matrix}\right\}\ 1890.0$$

If $\nu$ should equal + 4 the above elements would become almost identical with those determined by Bauschinger from the first appearance only and given by him in "Untersuchungen über den periodischen Kometen 1889 V" (Brooks), I Theil. A value of $\nu$ equal to + 0.1 will reduce Elements V to values nearly the same as those given by Bauschinger as the definitive elements from the first two appearances.

In order to determine the limits within which $\nu$ may vary I had recourse to the equations of condition which represent the three appearances and which are given in 24. In these I substituted various values of the corrections to the elements corresponding to different assumed values of $\nu$, and tabulated the resulting residuals. For $\nu$ equal to $\pm$ 0.1 the residuals, both in right ascension and declination, become far larger in the later appearances than the accuracy of modern observations warrants. Further, beyond these limits the residuals become systematic. Hence I conclude that the extreme possible limits of $\nu$ are $\pm$ 0.1; the probable limits are very much smaller than this.

# PART II.

## The Action of Jupiter upon the Comet During 1886.

28. Elements V, as given in Part I, and which represent the motion of the comet when first discovered, were made the basis of all investigations. These elements were first carried back by means of the perturbations during the interval 1889 and 1886, to October 26.5, 1886, on which date the comet emerged from Jupiter's "sphere of activity." During the preceding months, whilst the comet was traversing the "sphere of activity," Jupiter was considered as central and the sun as disturbing body, and during this time the comet was found to be travelling about Jupiter in a hyperbolic orbit. On March 24, 1886, the comet was so far from Jupiter that it became necessary to transfer the center of motion back again to the sun. For some time before this date, however, the perturbations of Jupiter were very large and were carefully computed.

In this manner were derived the elements, which best represent the motion of the comet in 1883 previous to its close approach to Jupiter in 1886.

29. *Perturbations between 1889 and 1886.* — With elements V, which are osculating for 1889, September 30.5, were computed the perturbations from that date to 1886, October 26.5. The perturbations by Jupiter during this period had previously been computed, but with elements which differed slightly from those adopted in this work. These old perturbations were integrated for the date of each new computation and the results applied to the adopted elements. With the elements thus derived for any given date the perturbations were recomputed, and when the action of Jupiter became very large, these perturbations were again integrated, applied, and the computations made anew. The final results were carefully checked by differencing and by independent computations.

During this interval the perturbations by the following planets were considered: Venus, the Earth, Mars, Jupiter and Saturn. The masses adopted for each are those as given in Part I, which differ slightly from those used in former investigations,[1] where the masses as given by Oppolzer were used. The perturbations due to Venus, the Earth, Mars and Saturn, were computed from 1889, September 30.5, to 1887, March 25.5. Between March 1887, and October 1886, the perturbations of Jupiter alone were taken into account.

From September 1889 to March 1887, a uniform interval of twenty days was used in the computations. At this latter date the perturbations of Jupiter became so large that it was necessary to reduce the interval to ten days. This interval was continued to December 25.5, 1886, when it again became necessary to reduce the interval, and from this date to October 26.5, 1886, a four day period was accordingly used.

The results, thus obtained, apply of course only to the mean values of the elements; that is, to that set of elements obtained by putting $\nu = 0$. The limits between which $\nu$ may vary are so small, however, that the perturbations computed with a set of elements corresponding to an extreme value of $\nu$ would not differ appreciably from those found as above. To be rigorously accurate the perturbations should be recomputed for different values of $\nu$, at least for the interval between March 1887 and October 1886. This would entail considerable labor for the mere sake of a degree of accuracy of no practical value. Hence I have applied the perturbations, as found above, directly to ELEMENTS V, without regard to any changes that might be introduced by the different values that $\nu$ may attain.

The computations were carried out as explained in Part I. and the results are contained in the following tables, which give the integrated values of the perturbations of the different elements for every forty days, until March 1887, before which date the table contains the integrated results for every date of computation.

[1] "Researches upon Comet V, 1889," *Astro. Jour.*, No. 302.

# Table XIII.

## Perturbations.

$\Delta\pi$

| Date. | Venus. | Earth. | Mars. | Jupiter. | Saturn. |
|---|---|---|---|---|---|
| | $''$ | $''$ | $''$ | $''$ | $''$ |
| 1887, Mch. 25.5 | +0.565 | — 7.003 | —0.065 | +1340.626 | +27.043 |
| May 4.5 | —1.433 | — 8.429 | +0.006 | + 922.556 | +25.823 |
| June 13.5 | —4.749 | — 8.553 | +0.032 | + 572.168 | +24.552 |
| July 23.5 | —5.558 | — 7.245 | +0.010 | + 281.583 | +23.232 |
| Sept. 1.5 | —2.762 | — 5.046 | —0.049 | + 44.161 | +21.869 |
| Oct. 11.5 | +0.702 | — 2.762 | —0.140 | — 144.906 | +20.467 |
| Nov. 20.5 | +0.852 | — 1.496 | —0.253 | — 288.792 | +19.032 |
| Dec. 30.5 | —2.870 | — 2.143 | —0.376 | — 390.465 | +17.568 |
| 1888, Feb. 8.5 | —6.538 | — 4.376 | —0.504 | — 454.756 | +16.081 |
| Mch. 19.5 | —6.091 | — 7.303 | —0.630 | — 485.814 | +14.581 |
| Apr. 28.5 | —1.951 | — 9.745 | —0.744 | — 488.606 | +13.075 |
| June 7.5 | +1.587 | —10.652 | —0.836 | — 467.088 | +11.566 |
| July 17.5 | +0.607 | — 9.732 | —0.900 | — 427.074 | +10.073 |
| Aug. 26.5 | —4.026 | — 7.298 | —0.922 | — 375.448 | + 8.619 |
| Oct. 5.5 | —7.445 | — 4.239 | —0.837 | — 316.102 | + 7.216 |
| Nov. 14.5 | —6.279 | — 1.766 | —0.687 | — 254.707 | + 5.886 |
| Dec. 24.5 | —1.869 | — 0.886 | —0.532 | — 195.802 | + 4.651 |
| 1889, Feb. 2.5 | +1.339 | — 2.282 | —0.359 | — 142.800 | + 3.538 |
| Mch. 14.5 | +0.253 | — 1.997 | —0.203 | — 98.109 | + 2.573 |
| Apr. 23.5 | —3.546 | — 1.715 | —0.086 | — 62.357 | + 1.776 |
| June 2.5 | —5.740 | — 3.380 | —0.010 | — 36.262 | + 1.152 |
| July 12.5 | —4.296 | — 3.229 | +0.028 | — 18.721 | + 0.684 |
| Aug. 21.5 | —1.256 | — 1.266 | —0.027 | 7.575 | + 0.325 |
| Sept. 30.5 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

## Perturbations.

$\Delta\Omega$

| Date. | Venus. | Earth. | Mars. | Jupiter. | Saturn. |
|---|---|---|---|---|---|
| | $''$ | $''$ | $''$ | $''$ | $''$ |
| 1887, Mch. 25.5 | —1.227 | +0.092 | —0.082 | +4503.224 | +4.552 |
| May 4.5 | —1.376 | +0.108 | —0.085 | +4172.686 | +4.495 |
| June 13.5 | —1.365 | +0.238 | —0.090 | +3796.361 | +4.412 |
| July 23.5 | —1.082 | +0.471 | —0.099 | +3399.927 | +4.306 |
| Sept. 1.5 | —0.793 | +0.719 | —0.110 | +2999.022 | +4.174 |
| Oct. 11.5 | —0.974 | +0.835 | —0.122 | +2604.979 | +4.020 |
| Nov. 20.5 | —0.875 | +0.693 | —0.134 | +2225.526 | +3.842 |
| Dec. 30.5 | —0.551 | +0.288 | —0.143 | +1868.657 | +3.641 |
| 1888, Feb. 8.5 | —0.265 | —0.214 | —0.149 | +1540.309 | +3.419 |
| Mch. 19.5 | —0.417 | —0.552 | —0.151 | +1242.804 | +3.182 |
| Apr. 28.5 | —0.718 | —0.538 | —0.147 | + 980.235 | +2.929 |
| June 7.5 | —0.221 | —0.164 | —0.137 | + 754.130 | —2.661 |
| July 17.5 | —0.583 | +0.430 | —0.123 | + 564.352 | +2.382 |
| Aug. 26.5 | —0.756 | +0.999 | —0.104 | + 409.241 | +2.096 |
| Oct. 5.5 | —0.070 | +1.273 | —0.069 | + 286.142 | +1.807 |
| Nov. 14.5 | —0.700 | +1.092 | —0.004 | + 191.736 | +1.518 |
| Dec. 24.5 | —0.699 | +0.513 | +0.056 | + 121.928 | +1.237 |
| 1889, Feb. 2.5 | 0.069 | —0.173 | +0.074 | + 72.955 | +0.968 |
| Mch. 14.5 | 0.720 | —0.608 | +0.064 | + 40.392 | +0.719 |
| Apr. 23.5 | —0.558 | —0.645 | +0.048 | + 19.783 | +0.495 |
| June 2.5 | +0.064 | —0.398 | +0.032 | + 8.138 | +0.305 |
| July 12.5 | —0.395 | —0.111 | +0.017 | + 2.461 | +0.159 |
| Aug. 21.5 | —0.246 | +0.004 | +0.006 | + 0.360 | +0.058 |
| Sept. 30.5 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

PERTURBATIONS.

$\Delta i$

| Date. | Venus. | Earth. | Mars. | Jupiter. | Saturn. |
|---|---|---|---|---|---|
| 1887, Mch. 25.5 | −0.313 | −0.186 | +0.006 | +1590.890 | +0.618 |
| May 4.5 | −0.476 | −0.172 | +0.005 | +1231.222 | +0.556 |
| June 13.5 | −0.475 | −0.080 | +0.001 | + 955.443 | +0.496 |
| July 23.5 | −0.325 | +0.046 | −0.005 | + 740.375 | +0.438 |
| Sept. 1.5 | −0.200 | +0.151 | −0.009 | + 570.055 | +0.382 |
| Oct. 11.5 | −0.254 | +0.193 | −0.013 | + 434.374 | +0.329 |
| Nov. 20.5 | −0.239 | +0.156 | −0.017 | + 325.982 | +0.278 |
| Dec. 30.5 | −0.152 | +0.058 | −0.019 | + 240.142 | +0.231 |
| 1888, Feb. 8.5 | −0.099 | −0.035 | −0.021 | + 172.957 | +0.186 |
| Mch. 19.5 | +0.021 | −0.084 | −0.021 | + 120.895 | +0.145 |
| Apr. 28.5 | +0.068 | −0.084 | −0.021 | + 81.594 | +0.106 |
| June 7.5 | +0.006 | −0.037 | −0.020 | + 52.647 | +0.072 |
| July 17.5 | −0.081 | +0.027 | −0.018 | + 32.054 | +0.042 |
| Aug. 26.5 | −0.098 | +0.078 | −0.016 | + 17.986 | +0.016 |
| Oct. 5.5 | −0.050 | +0.099 | −0.013 | + 8.872 | −0.006 |
| Nov. 14.5 | −0.004 | +0.089 | −0.009 | + 3.392 | −0.023 |
| Dec. 24.5 | −0.002 | +0.066 | −0.006 | + 0.452 | −0.035 |
| 1889, Feb. 2.5 | −0.021 | +0.047 | −0.005 | − 1.003 | −0.042 |
| Mch. 14.5 | −0.028 | +0.042 | −0.005 | − 1.278 | −0.043 |
| Apr. 23.5 | −0.033 | +0.039 | −0.005 | − 1.063 | −0.040 |
| June 2.5 | −0.054 | +0.029 | −0.005 | − 0.669 | −0.034 |
| July 12.5 | −0.075 | +0.010 | −0.004 | − 0.302 | −0.024 |
| Aug. 21.5 | −0.056 | −0.001 | −0.002 | − 0.068 | −0.012 |
| Sept. 30.5 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

PERTURBATIONS.

$\Delta\phi$

| Date. | Venus. | Earth. | Mars. | Jupiter. | Saturn. |
|---|---|---|---|---|---|
| 1887, Mch. 25.5 | +0.438 | −4.261 | +0.293 | +4375.975 | +5.232 |
| May 4.5 | −1.689 | −3.938 | +0.270 | +3434.259 | +4.764 |
| June 13.5 | −2.570 | −2.897 | +0.224 | +2718.908 | +4.316 |
| July 23.5 | −1.333 | −1.610 | +0.166 | +2165.647 | +3.890 |
| Sept. 1.5 | +0.538 | −0.601 | +0.108 | +1730.339 | +3.487 |
| Oct. 11.5 | +1.035 | −0.270 | +0.054 | +1384.950 | +3.110 |
| Nov. 20.5 | −0.260 | −0.741 | +0.011 | +1109.352 | +2.757 |
| Dec. 30.5 | −1.764 | −1.735 | −0.019 | + 889.282 | +2.439 |
| 1888, Feb. 8.5 | −1.761 | −2.786 | −0.035 | + 713.917 | +2.152 |
| Mch. 19.5 | −0.414 | −3.316 | −0.031 | + 573.271 | +1.891 |
| Apr. 28.5 | +0.658 | −3.079 | −0.007 | + 460.900 | +1.665 |
| June 7.5 | +0.317 | −2.335 | +0.033 | + 370.751 | +1.472 |
| July 17.5 | −0.870 | −1.477 | +0.087 | + 297.989 | +1.314 |
| Aug. 26.5 | −1.319 | −0.906 | +0.149 | + 238.568 | +1.192 |
| Oct. 5.5 | −0.410 | −0.890 | +0.238 | + 189.393 | +1.115 |
| Nov. 14.5 | +0.748 | −1.441 | +0.311 | + 148.064 | +1.071 |
| Dec. 24.5 | +0.716 | −2.264 | +0.326 | + 112.745 | +1.039 |
| 1889, Feb. 2.5 | −0.552 | −2.759 | +0.314 | + 82.782 | +1.019 |
| Mch. 14.5 | −1.513 | −3.423 | +0.277 | + 57.517 | +0.997 |
| Apr. 23.5 | −0.747 | −3.388 | +0.224 | + 36.345 | +0.950 |
| June 2.5 | +1.276 | −2.126 | +0.166 | + 19.856 | +0.847 |
| July 12.5 | +2.749 | −0.972 | +0.108 | + 8.278 | +0.661 |
| Aug. 21.5 | +2.228 | −0.240 | +0.050 | + 1.748 | +0.375 |
| Sept. 30.5 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

PERTURBATIONS.

$\Delta\mu$

| Date. | Venus. | Earth. | Mars. | Jupiter. | Saturn. |
|---|---|---|---|---|---|
| | " | " | " | " | " |
| 1887, Mch. 25.5 | +0.0064 | +0.0009 | —0.0007 | +2.9885 | +0.0386 |
| May 4.5 | +0.0012 | —0.0006 | —0.0006 | +1.2925 | +0.0365 |
| June 13.5 | —0.0043 | +0.0004 | —0.0006 | +0.0637 | +0.0343 |
| July 23.5 | —0.0045 | +0.0033 | —0.0007 | —0.8263 | +0.0320 |
| Sept. 1.5 | +0.0010 | +0.0075 | —0.0008 | —1.4608 | +0.0296 |
| Oct. 11.5 | +0.0069 | +0.0113 | —0.0010 | —1.8954 | +0.0272 |
| Nov. 20.5 | +0.0070 | +0.0133 | —0.0012 | —2.1683 | +0.0247 |
| Dec. 30.2 | +0.0006 | +0.0124 | —0.0014 | —2.3079 | +0.0222 |
| 1888, Feb. 8.5 | —0.0061 | +0.0088 | —0.0016 | —2.3396 | +0.0196 |
| Mch. 19.5 | —0.0064 | +0.0037 | —0.0019 | —2.2811 | +0.0170 |
| Apr. 28.5 | +0.0004 | —0.0012 | —0.0021 | —2.1551 | +0.0144 |
| June 7.5 | +0.0078 | —0.0041 | —0.0024 | —1.9773 | +0.0118 |
| July 17.5 | +0.0082 | —0.0040 | —0.0026 | —1.7610 | +0.0092 |
| Aug. 26.5 | +0.0001 | —0.0006 | —0.0028 | —1.5237 | +0.0066 |
| Oct. 5.5 | —0.0089 | +0.0053 | —0.0028 | —1.2758 | +0.0042 |
| Nov. 14.5 | —0.0104 | +0.0116 | —0.0028 | —1.0306 | +0.0019 |
| Dec. 24.5 | —0.0024 | +0.0162 | —0.0026 | —0.7979 | —0.0002 |
| 1889, Feb. 2.5 | +0.0082 | +0.0158 | —0.0022 | —0.5892 | —0.0020 |
| Mch. 14.5 | +0.0109 | +0.0192 | —0.0018 | —0.4068 | —0.0034 |
| Apr. 23.5 | +0.0020 | +0.0183 | —0.0014 | —0.2542 | —0.0042 |
| June 2.5 | —0.0114 | +0.0109 | —0.0010 | —0.1371 | —0.0044 |
| July 12.5 | —0.0186 | +0.0044 | —0.0006 | —0.0566 | —0.0037 |
| Aug. 21.5 | —0.0138 | +0.0010 | —0.0003 | —0.0120 | —0.0022 |
| Sept. 30.5 | 0. 000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

PERTURBATIONS.

$(\Delta L)_{\prime}$

| Date. | Venus. | Earth. | Mars. | Jupiter. | Saturn. |
|---|---|---|---|---|---|
| | " | " | " | " | " |
| 1887, Mch. 25.5 | —6.880 | —5.223 | —0.548 | +5869.985 | —0.053 |
| May 4.5 | —7.802 | —3.118 | —0.667 | +4921.385 | +0.673 |
| June 13.5 | —5.575 | —1.254 | —0.773 | +4128.439 | +1.333 |
| July 23.5 | —2.540 | —0.318 | —0.854 | +3453.533 | +1.926 |
| Sept. 1.5 | —1.680 | —0.559 | —0.907 | +2871.316 | +2.448 |
| Oct. 11.5 | —3.663 | —1.852 | —0.934 | +2365.755 | +2.898 |
| Nov. 20.5 | —6.387 | —3.699 | —0.938 | +1925.235 | +3.274 |
| Dec. 30.5 | —7.027 | —5.324 | —0.918 | +1542.754 | +3.573 |
| 1888, Feb. 8.5 | —4.955 | —6.257 | —0.877 | +1214.364 | +3.794 |
| Mch. 19.5 | —2.296 | —6.031 | —0.812 | + 933.816 | +3.937 |
| Apr. 28.5 | —1.516 | —4.662 | —0.726 | + 698.566 | +3.999 |
| June 7.5 | —3.145 | —2.884 | —0.619 | + 506.070 | +3.978 |
| July 17.5 | —5.461 | —1.263 | —0.497 | + 351.938 | +3.880 |
| Aug. 26.5 | —6.153 | —0.240 | —0.376 | + 233.093 | +3.708 |
| Oct. 5.5 | —4.602 | —0.035 | —0.202 | + 143.122 | +3.464 |
| Nov. 14.5 | —2.306 | —0.635 | —0.048 | + 78.691 | +3.158 |
| Dec. 24.5 | —1.210 | —1.774 | +0.016 | + 34.907 | +2.794 |
| 1889, Feb. 2.5 | —2.026 | —3.064 | +0.058 | + 7.912 | +2.382 |
| Mch. 14.5 | —3.831 | —3.626 | +0.077 | — 6.502 | +1.937 |
| Apr. 23.5 | —4.940 | —3.605 | +0.077 | — 12.430 | +1.477 |
| June 2.5 | —4.355 | —3.374 | +0.066 | — 12.608 | +1.030 |
| July 12.5 | —2.430 | —2.454 | +0.050 | — 9.452 | +0.619 |
| Aug. 21.5 | —0.576 | —0.891 | +0.026 | — 4.801 | +0.269 |
| Sept. 30.5 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

PERTURBATIONS.

$(\Delta L)_{\prime\prime}$

| Date. | | Venus. | Earth. | Mars. | Jupiter. | Saturn. |
|---|---|---|---|---|---|---|
| 1887, | Mch. 25.5 | +1.2346″ | −6.1741″ | +1.4287″ | + 902.8671″ | −11.6023″ |
| | May 4.5 | +1.3981 | −6.1760 | +1.4034 | + 986.6405 | −10.1000 |
| | June 13.5 | +1.3233 | −6.1880 | +1.3789 | +1012.4483 | − 8.6848 |
| | July 23.5 | +1.1232 | −6.1198 | +1.3525 | + 996.2306 | − 7.3595 |
| | Sept. 1.5 | +1.0414 | −5.9051 | +1.3218 | + 949.7444 | − 6.1271 |
| | Oct. 11.5 | +1.2104 | −5.5257 | +1.2851 | + 882.0238 | − 4.9902 |
| | Nov. 20.5 | +1.5147 | −5.0242 | +1.2410 | + 800.2597 | − 3.9513 |
| | Dec. 30.5 | +1.6829 | −4.4992 | +1.1888 | + 710.3389 | − 3.0125 |
| 1888, | Feb. 8.5 | +1.5609 | −4.0701 | +1.1277 | + 617.0640 | − 2.1757 |
| | Mch. 19.5 | +1.2840 | −3.8162 | +1.0573 | + 524.3540 | − 1.4425 |
| | Apr. 28.5 | +1.1481 | −3.7720 | +0.9771 | + 435.4884 | − 0.8138 |
| | June 7.5 | +1.3242 | −3.8883 | +0.8873 | + 352.6614 | − 0.2900 |
| | July 17.5 | +1.6767 | −4.0616 | +0.7882 | + 277.7935 | + 0.1289 |
| | Aug. 26.5 | +1.8632 | −4.1623 | +0.6806 | + 212.0503 | + 0.4451 |
| | Oct. 5.5 | +1.6736 | −4.0734 | +0.5674 | + 156.0506 | + 0.6614 |
| | Nov. 14.5 | +1.2516 | −3.7329 | +0.4536 | + 109.9511 | + 0.7826 |
| | Dec. 24.5 | +0.9698 | −3.1678 | +0.3457 | + 73.4285 | + 0.8154 |
| 1889, | Feb. 2.5 | +1.0963 | −2.5016 | +0.2492 | + 45.7991 | + 0.7701 |
| | Mch. 14.5 | +1.5200 | −1.8547 | +0.1681 | + 25.9489 | + 0.6611 |
| | Apr. 23.5 | +1.8111 | −1.0091 | +0.1037 | + 12.8498 | + 0.5074 |
| | June 2.5 | +1.6167 | −0.4124 | +0.0560 | + 5.1461 | + 0.3331 |
| | July 12.5 | +0.9842 | −0.1126 | +0.0239 | + 1.3946 | + 0.1682 |
| | Aug. 21.5 | +0.2926 | −0.0164 | +0.0057 | + 0.1387 | + 0.0464 |
| | Sept. 30.5 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

JUPITER.

| Date. | | $\Delta\pi$ | $\Delta\Omega$ | $\Delta i$ | $\Delta o$ | $\Delta u$ | $(\Delta L)_{\prime}$ | $(\Delta L)_{\prime\prime}$ |
|---|---|---|---|---|---|---|---|---|
| 1886, | Oct. 26.5 | +1217.886″ | −779.358″ | +2012.373″ | −5377.576″ | −10.4522″ | +3857.810″ | −272.2219″ |
| | " 30.5 | +1122.561 | −673.377 | +1818.810 | +4862.222 | − 9.4471 | −3507.432 | −232.4439 |
| | Nov. 3.5 | +1029.458 | −578.354 | −1637.588 | +4378.267 | − 8.5034 | −2175.942 | −196.5632 |
| | " 7.5 | + 939.065 | −493.210 | +1467.368 | +3923.140 | − 7.6163 | +2861.037 | −164.3414 |
| | " 11.5 | + 850.846 | −416.797 | +1306.563 | +3493.844 | − 6.7799 | +2561.397 | −135.5650 |
| | " 15.5 | + 764.643 | −348.652 | +1154.859 | +3088.515 | − 5.9906 | +2276.200 | −110.0391 |
| | " 19.5 | + 680.572 | −288.063 | +1011.364 | +2705.042 | − 5.2443 | +2003.795 | − 87.5829 |
| | " 23.5 | − 598.385 | −234.458 | + 875.547 | +2341.825 | − 4.5378 | −1743.549 | 68.0315 |
| | " 29.5 | + 517.984 | −187.257 | + 746.746 | +1997.145 | 3.8679 | −1494.445 | − 51.2313 |
| | Dec. 1.5 | + 439.092 | −145.894 | − 624.270 | +1669.302 | − 3.2311 | +1255.665 | − 37.0440 |
| | " 5.5 | + 361.675 | −110.132 | − 507.527 | +1357.396 | − 2.6258 | +1026.352 | − 25.3405 |
| | " 9.5 | + 286.189 | − 79.458 | − 396.351 | −1060.352 | − 2.0502 | − 805.555 | − 15.9980 |
| | " 13.5 | − 212.413 | − 53.324 | − 290.483 | + 776.953 | − 1.5014 | − 593.029 | − 8.9034 |
| | " 17.5 | + 140.212 | − 31.581 | − 189.381 | + 506.408 | − 0.9779 | + 388.524 | − 3.9529 |
| | " 21.5 | + 69.458 | − 13.902 | + 92.661 | + 247.684 | − 0.4778 | − 191.083 | − 0.9488 |
| | " 25.5 | 0.000 | 0.000 | 0.000 | 0.000 | 0.0000 | 0.000 | 0.0000 |
| 1886, | Dec. 25.5 | +1263.083 | +305.283 | +1377.997 | +3660.060 | − 6.9298 | +3119.291 | −267.9356 |
| 1887, | Jan. 4.5 | +1094.905 | − 324.741 | +1162.542 | +3085.056 | − 5.8228 | +2669.067 | −204.2753 |
| | " 14.5 | + 935.156 | +325.656 | + 968.208 | +2566.675 | − 4.8288 | +2253.033 | −151.1040 |
| | " 24.5 | + 782.732 | +310.882 | − 791.755 | −2096.568 | − 3.9312 | +1866.634 | −107.3791 |
| | Feb. 3.5 | + 637.070 | −282.757 | + 630.784 | +1668.352 | − 3.1173 | +1506.232 | − 72.2018 |
| | " 13.5 | + 497.975 | +243.282 | + 483.369 | +1276.832 | − 2.3773 | +1168.553 | − 44.7870 |
| | " 23.5 | + 365.076 | +193.953 | + 347.893 | + 917.807 | − 1.7024 | − 851.122 | − 24.4395 |
| | Mch. 5.5 | + 238.065 | +136.046 | + 222.826 | + 587.256 | − 1.0852 | − 551.402 | − 10.5468 |
| | " 15.5 | + 116.497 | + 71.028 | + 107.120 | + 282.079 | − 0.5197 | − 267.960 | 2.5628 |
| | " 25.5 | 0.000 | 0.000 | 0.000 | 0.000 | 0.0000 | 0.000 | 0.0000 |

From the above tables I find directly the total changes in the elements during the interval 1889, Sept. 30.5, to 1886, Oct. 26.5, as follows:

$$
\begin{aligned}
\Delta\mu &= +\ 20''.41570 \\
\Delta\pi &= +1^\circ\ 4'\ 2''.14 \\
\Delta\Omega &= +1\ \ 7\ 12\ .48 \\
\Delta\varphi &= +3\ 43\ 35\ .31 \\
\Delta i &= +1\ 23\ \ 1\ .38 \\
\Delta L_1 &= +3\ 33\ 54\ .38 \\
\Delta L_{11} &= +0\ \ 5\ 27\ .60
\end{aligned}
$$

In applying $\Delta L_1$ and $\Delta L_{11}$, as above given, it must be noted that proper values of $\mu$ must be used for the intervals between 1889, March and 1887, March; 1887, March and 1886, December; and 1886, December and 1886, October.

Applying these perturbations to Elements V, and at the same time reducing them to the mean equator and equinox of 1886.0, I have for osculating elements, which represent the motion of the comet, at the moment it left Jupiter's "sphere of activity":

Epoch, 1886, Oct. 26.5, Greenwich M. T.

$$
\begin{aligned}
\mu &= 522''.09645 \quad + 0''.0114v \\
&\left.\begin{aligned}
L &= 215^\circ 51' 26''.92 - 14\ .2747v \\
\pi &= \ \ 2\ 35\ 49\ .24 - \ 3\ .0767v \\
\Omega &= 19\ \ 2\ 59\ .79 - \ 0\ .0174v \\
\phi &= 31\ 48\ 47\ .68 - \ 1\ .3961v \\
i &= \ \ 7\ 27\ \ 5\ .78 - \ 0\ .1140v
\end{aligned}\right\} 1886.0 \\
M_0 &= 213\ 15\ 37\ .68 - 11\ .1980v
\end{aligned}
$$

30. *Transformation to Jupiter as Center of Motion.*—The general method used, which was first proposed by D'Alembert, consists in supposing the planet to have a "sphere of activity," within which the relative motion of the comet is affected only by the planet's attraction and beyond which the absolute motion of the comet about the sun is performed as if the sun alone acted upon it. The radius of the sphere depends upon the mass of the planet and its distance from the sun. This was the simple method afterwards used by LaPlace and again by Le-Verrier. But while beautiful and simple, it neglects entirely the effect of the sun as disturbing body whilst the comet is

traversing its relative orbit about the planet. It will become more effective, if we merely use the idea of the "sphere" as defining approximately the point, at which we may conveniently transpose the sun and the planet, as disturbing and central bodies; and after the transformation has been made, we may treat the sun and the comet as bodies revolving about the planet as central body; the sun acting as a disturbing body upon the comet. The perturbations of the comet by the sun may be computed in a manner entirely similar to the usual methods. The exact point in the comet's orbit, at which the transformation is made, is of no great importance, provided the perturbations be carefully computed both before and after; and this fact furnishes us with the desired, and an absolute, control.

As the comet approaches Jupiter in its orbit about the sun, compute carefully the planetary perturbations, thus deriving the osculating elliptic elements of the comet for two dates, $t$ and $t'$, one of which, $t$, is that upon which the comet enters the so called "sphere," the other, $t'$, being ten days or two weeks later, or after the comet is well within the sphere. From the osculating elements of date $t$ compute the heliocentric coördinates and their derivatives for that date, thence find the coördinates and velocities relative to Jupiter, and thence by the transformation-formulas the osculating hyperbola about Jupiter; with these hyperbolic elements compute the solar perturbations for the interval $t' - t$, apply them and thus derive the osculating hyperbola for the date $t'$. With these elements we may readily compute the coördinates, $x'$, $y'$, $z'$, of the comet referred to Jupiter for the date $t'$.

Then with the osculating elliptic elements of the comet about the sun, as already derived for the date, $t'$, we compute first the heliocentric coördinates of the comet and thence derive the coördinates, $x''$, $y''$, $z''$, of the comet referred to Jupiter for the date $t'$. If all formulas and computations are correct, we shall have absolutely,

$$x' = x'' \qquad y' = y'' \qquad z' = z''$$

and a perfect control is secured.

The most convenient point to make the transformation to Jupiter as center of motion is undoubtedly that given by LaPlace's idea of the "sphere of activity." The radius of this sphere, as given by LaPlace[1] is

$$\rho = r\sqrt[5]{\tfrac{1}{2}m'^2}$$

where $\rho$ is the radius of the sphere,
$r$ is the radius vector of the comet,
$m'$ is the mass of the planet.

Using Newcomb's value of the mass of Jupiter, I find

$$\log\frac{\rho}{r} = 8.73176$$

and the date which most nearly satisfies this condition is October 26.5, 1886, at which time I find

$$\log\frac{\rho}{r} = 8.72954$$

31. From the osculating elements of the comet for October 26.5, as given in § 29, were derived by the usual formulas of elliptic motion the heliocentric rectangular coördinates and their derivatives with respect to the time. The ecliptic of 1886.0 was taken as fundamental plane; the positive direction of the axis of $x$ being directed toward the Vernal Equinox. Thus were found,

$$\log\ x = 0.7127116\,n$$
$$\log\ y = 0.1394713\,n$$
$$\log\ z = 8.6977660$$
$$\log\frac{dx}{dt} = 7.3948617$$
$$\log\frac{dy}{dt} = 7.6680856\,n$$
$$\log\frac{dz}{dt} = 6.8335871\,n$$

The corresponding coördinates and velocities for Jupiter were found as follows. The heliocentric position of Jupiter in 1886,

[1] *Mécanique Céleste*, Livre IV.

October 26.5, was taken from the British Nautical Almanac, the latitude and longitude being reduced to the mean equinox of 1886.0. To find the derivatives of the quantities I took from the Almanac a series of complete positions of the planet at four-day intervals, reducing each to the same mean equinox. The longitudes, for example, were tabulated and the differences found to the fifth order, and from these differences, by means of the formulas for interpolation, was found the value the first difference should have at the required date. Dividing this by four, was found very accurately the daily rate of change of the longitude, which is the derivative required. The necessary data for Jupiter ar thus:

$$\begin{aligned} \lambda \quad & 197^\circ\ 38'\ 31''.19 \\ \beta = + \quad & 1\ \ 17\ \ 46.32 \\ \log r = \quad & 0.7368529 \\ \Delta\lambda = + \quad & 0^\circ\ \ 4'\ 31''.749 \\ \Delta\beta = - \quad & 0''.88125 \\ \Delta \log r = - \quad & 0.0000025525 \end{aligned}$$

From these the rectangular coördinates and their derivatives were easily computed, and subtracting these results from the corresponding quantities for the comet, as given above, I find for the coördinates and their derivatives of the comet relative to Jupiter,

$$\begin{aligned} \log x &= 8.5690896 \\ \log y &= 9.4382768 \\ \log z &= 8.8665992\ n \\ \log \frac{dx}{dt} &= 6.4384763 \\ \log \frac{dy}{dt} &= 7.3387872 \\ \log \frac{dz}{dt} &= 6.8180026\ n \end{aligned}$$

32. The elements of the orbit of the comet about Jupiter may be found from the above coördinates and velocities by means of the integrals derived from the equations of motion of one body around another. These integrals are given by LaPlace[1] in the following form:

[1] *Mécanique Céleste*, Livre II.

$$C=\frac{xdy-ydx}{dt}, \quad C'=\frac{xdz-zdx}{dt}, \quad C''=\frac{ydz-zdy}{dt}$$

$$o=f+x\left[\frac{k^2}{r}-\frac{dy^2+dz^2}{dt^2}\right]+\frac{ydydz}{dt^2}+\frac{zdzdx}{dt^2}$$

$$o=f'+y\left[\frac{k^2}{r^2}-\frac{dx^2+dz^2}{dt^2}\right]+\frac{xdxdy}{dt^2}+\frac{zdzdy}{dt^2}$$

$$o=\frac{k^2}{a}-\frac{2k^2}{r}+V^2$$

where $C$, $C'$, $C''$, $f$, $f'$, and $a$ are the arbitrary constants of integration. The ordinary elements of an orbit are arbitrary constants, and are, consequently functions of the above constants, being given by the following formulas :

$$\tan \Omega=\frac{C''}{C'},$$

$$\tan i=\frac{\sqrt{C'^2+C''^2}}{C},$$

$$\tan I=\frac{f'}{f},$$

$$h^2=C'^2+C''^2+C^2,$$

$$e=\sqrt{1-\frac{h^2}{k^2a}},$$

where $I$ is the longitude of the projection of the perihelion on the fundamental plane.

In the special problem under consideration, $k^2$, in the above formulas, becomes the acceleration at unit distance due to the force exerted by the mass of Jupiter. Using Newcomb's determination of the mass of Jupiter, I have

$$\log k^2=3.4510772.$$

From the above formulas were derived the values for the three constants of area, $C$, $C'$, $C''$, and for the semi-axis major of the comet's orbit about Jupiter, namely,

$$\begin{aligned}\log C &= 4.7477148\\ \log C' &= 4.6228470\ n\\ \log C'' &= 5.2999551\ n\\ \log a &= 8.9332651\ n.\end{aligned}$$

and consequently the relative orbit was hyperbolic.

From these were derived the complete hyperbolic elements, which represent the osculating hyperbola in which the comet was moving about Jupiter on 1886, October 26.5.

These elements are as follows:

Epoch, 1886, October 26.5.

$$\begin{aligned}
\pi &= 283^\circ 21' 28.''25 + 271.''290\nu \\
\Omega &= 258\ \ 7\ 20.\ 50 - \ \ 12.\ 294\nu \\
i &= \ \ 74\ 39\ 23.\ 47 - \ \ 97.\ 957\nu \\
\omega &= \ \ 25\ 14\ \ 7.\ 75 + 258.\ 996\nu \\
a &= -0.0857561 + 0.0000098\nu \\
e &= \ \ \ 1.0093523 + 0.0001826\nu \\
N &= +0.9046965 + 0.0009094\nu
\end{aligned}$$

and the time of peri-jovian passage, neglecting the effect of solar perturbations, is

$$1886,\ \text{July } 20.0813 - 0.0819\nu$$

The values of the coefficients of $\nu$ in the hyperbola about Jupiter were found in the following manner. In the elliptic elements for October 26.5, $\nu$ was given a value of +, 10 and from the resulting elements were derived the corresponding hyperbolic elements in a manner entirely similar to that explained above. The differences between the elements thus found and the corresponding elements for $\nu = 0$ were divided by 10 and the results of this division are the coefficients of $\nu$ as given above.

The entire computation of these elements was checked by means of the control explained in § 30. In my work, the date chosen to make the transformation to Jupiter as the center of motion was, as has already been given, 1886 October, 26.5; the interval, $t' - t$, was taken as sixteen days, thus making the check-date October 10.5. A longer check-interval cannot well be used, for the perturbations of the elliptic elements become more and more difficult of computation as we advance nearer and nearer to Jupiter. I first applied to the hyperbolic elements for October 26.5 that correspond to $\nu$ equal to zero, the solar perturbations for sixteen days; thus deriving the osculating hyperbolic elements for October 10.5. From these I then found

the rectangular coördinates, $x'$, $y'$, $z'$, of the comet referred to Jupiter. Then to the elliptic elements of October 26.5 I applied the perturbations due to Jupiter for the same interval, and thus found the osculating elliptic elements of the comet about the sun for October 10.5. From these I then computed the heliocentric coördinates of the comet and thence the rectangular coördinates, $x''$, $y''$, $z''$, of the comet referred to Jupiter. Comparing the two sets of results thus found, I have as follows:

$$x'' - x' = +0.000026$$
$$y'' - y' = -0.000042$$
$$z'' - z' = +0.000061$$

These differences are all considerably less than a tenth of one per cent. of the corresponding quantities, that in $z$ being relatively by far the largest. Such errors may well arise from the unavoidable use of mathematical tables, and are small enough to establish the substantial accuracy of both methods and computations.

33. *Solar Perturbations, October to March, 1886.* — During the time that the comet was traversing the relative orbit about Jupiter, the sun acted as a disturbing body and this action had to be taken account of. In order to do this I computed the solar perturbations for the entire interval between October and March, using an eight-day period. The method used in this work was that of the variation of constants, the necessary formulas being derived from the equations of hyperbolic motion as given by Watson. The quantities of which the perturbations were found are as follows: the four elements, $\pi$, $\Omega$, $i$, and $e$ and the two auxiliaries, $\nu$ and $N$ (Watson's notation). In this form I found the perturbations very easy of computation, and the method, on the whole, decidedly preferable to that of the variation of coördinates, which I had used in a former discussion of the same problem. The great trouble with this latter method is that the indirect terms of the differential coefficients, owing to the very small value of $r$, become large and difficult to approximate. This necessitates the integration of

the perturbations, their application, and the derivation of new osculating elements at several epochs during the interval under discussion.

The differential variations of the quantities with respect to the time, with the exception of $N$, were put in the ordinary standard form :

$$\omega \frac{d\pi}{dt} = (\pi : R) R + (\pi : S) S + (\pi : W) W$$

while that of $N$ was put into the form :

$$\omega \frac{dN}{dt} = (N : v)\, \omega \frac{dv}{dt} + (N : e)\, \omega \frac{de}{dt},$$

in which formulas, $R$, $S$ and $W$ are the component disturbing forces and the quantities $(\pi : R)$, etc., are the differential coefficients of the elements. From the numerical values of the above variations, as computed for equidistant intervals of time, the total change in the elements from one period to another, may be found by simple mechanical quadrature.

The component disturbing forces, $R$, $S$ and $W$ were computed by the usual formulas, as given in Oppolzer, but were expressed in radians and in units of the sixth decimal place.

The formulas for the differential coefficients of the elements are as follows, where $\omega$ is the number of days interval between computations and the quantities in brackets are logarithms :

$$(i : W) = r \cos u \; [9.31442]$$

$$(\Omega : W) = \frac{r \sin u}{\sin i} \; [9.31442]$$

$$(\pi : R) = -\frac{p \cos v}{e} \; [9.31442]$$

$$(\pi : S) = (p + r) \frac{\sin v}{e} \; [9.31442]$$

$$(\pi : W) = r \sin u \tan \tfrac{1}{2} i \; [9.31442]$$

$$(\nu : R) = 3 \nu a \omega e \sin v$$

$$(\nu : S) = 3 \nu a \omega \frac{p}{r}$$

$$(e : R) = p \sin v$$

$$(e:S) = p \cos v + \frac{p}{\cos F.}$$

$$(N:\nu) = \frac{2\lambda r \sin \psi}{3\nu a \sin v}$$

$$(N:e) = -\lambda \sin \psi \cos v.$$

In these formulas, $a$, the semi-axis major is always taken as positive and $\psi$, $\nu$, $N$, and $F$ are auxiliary quantities in the hyperbola, analogous to the quantities, $\varphi$, $\mu$, $M$, and $E$, in the ellipse, and are given by the equations,

$$\cos \psi = \frac{1}{e},$$

$$\nu = \frac{\lambda k}{a^{\frac{3}{2}}},$$

$$N = \nu(t - T_0)$$

$$e\lambda \tan F = N + \log \tan (45^\circ + \tfrac{1}{2}F)$$

where $\lambda$ is the modulus of common logarithms.

The perturbation of $N$ is given in the form

$$\Delta N = (\Delta N)_{\prime} + (\Delta N)_{\prime\prime}$$

where $(\Delta N)_1$ is derived directly by mechanical quadrature from the above formula, and

$$(\Delta N)_{\prime\prime} = \omega^2 \int \int \frac{d\nu}{dt}\, dt^2,$$

this being derived by double integration from the variation of $\nu$ as computed above.

The integrated perturbations, as thus computed, are given in the following table; in which the changes in $e$, $\nu$, and $N$ are expressed in units of the sixth decimal place.

## Table XIV.

### Solar Perturbations.

| Date. | $\Delta\pi$ | $\Delta\Omega$ | $\Delta i$ | $\Delta e$ | $\Delta v$ | $(\Delta N)_{\prime}$ | $(\Delta N)_{\prime\prime}$ |
|---|---|---|---|---|---|---|---|
| Mch. 24.5 | +1902.″6 | −7270.″2 | −40174.″5 | −1683.2 | −425.2 | +71735.3 | −31639.2 |
| Apr. 1.5 | +509.5 | −9146.2 | −42272.9 | +1917.7 | −341.0 | +63561.3 | −34702.0 |
| 9.5 | −587.4 | −10606.0 | −43882.4 | +2120.8 | 259.8 | +56217.9 | −37102.8 |
| 17.5 | −1430.5 | −11707.5 | −45080.6 | +2293.5 | −181.9 | +49682.5 | −38867.2 |
| 25.5 | −2063.2 | −12512.7 | −45945.2 | +2438.1 | −107.4 | +43931.7 | −40021.9 |
| May 3.5 | −2529.6 | −13085.4 | −46553.3 | +2558.5 | −36.7 | +38935.2 | −40595.7 |
| 11.5 | −2860.8 | −13471.7 | −46959.0 | +2657.6 | +30.1 | +34658.8 | −40619.4 |
| 19.5 | −3081.4 | −13707.7 | −47204.0 | +2738.0 | +92.7 | +31064.5 | −40125.4 |
| 27.5 | −3223.2 | −13838.2 | −47338.1 | +2803.6 | +151.0 | +28110.7 | −39147.7 |
| June 4.5 | −3309.0 | −13897.7 | −47398.5 | +2857.5 | +204.6 | +25751.9 | −37722.5 |
| 12.5 | −3357.8 | −13913.3 | −47414.2 | +2902.3 | +253.2 | +23938.4 | −35888.0 |
| 20.5 | −3387.8 | −13910.9 | −47411.9 | +2940.5 | +296.7 | +22616.6 | −33684.8 |
| 28.5 | −3408.3 | −13904.0 | −47405.3 | +2973.0 | +334.4 | +21729.0 | −31156.6 |
| July 6.5 | −3427.9 | −13903.8 | −47404.8 | +3000.7 | +365.6 | +21211.2 | −28351.6 |
| 14.5 | −3448.9 | −13914.4 | −47414.0 | +3023.5 | +390.0 | +20992.3 | −25325.0 |
| 22.5 | −3464.7 | −13924.5 | −47408.3 | +3029.0 | +396.0 | +20951.4 | −22160.4 |
| 30.5 | −3489.7 | −13899.4 | −47245.4 | +3006.1 | +383.1 | +20874.0 | −19039.9 |
| Aug. 7.5 | −3531.1 | −13791.7 | −46764.4 | +2953.0 | +364.0 | +20603.4 | −16047.4 |
| 15.5 | −3571.3 | −13561.8 | −45878.2 | +2863.7 | +340.0 | +20088.8 | −13228.4 |
| 23.5 | −3598.6 | −13176.2 | −44496.7 | +2733.0 | +312.0 | +19285.7 | −10618.1 |
| 31.5 | −3598.6 | −12600.1 | −42516.7 | +2555.8 | +280.6 | +18162.1 | −8245.6 |
| Sept. 8.5 | −3552.1 | −11797.3 | −39823.7 | +2328.2 | +246.4 | +16693.4 | −6135.8 |
| 16.5 | −3434.0 | −10732.7 | −36296.2 | +2048.6 | +209.7 | +14859.6 | −4309.8 |
| 24.5 | −3210.4 | −9369.2 | −31790.6 | +1717.5 | +170.8 | +12647.8 | −2786.4 |
| Oct. 2.5 | −2832.1 | −7661.4 | −26123.0 | +1338.1 | +130.2 | +10053.0 | −1581.4 |
| 10.5 | −2236.0 | −5566.9 | −19100.6 | +917.3 | +87.9 | +7073.2 | −708.1 |
| 18.5 | −1332.4 | −3033.2 | −10486.2 | +466.0 | +44.4 | +3713.8 | −178.2 |
| 26.5 | 0.0 | 0.0 | 0.0 | 0.0 | +0.0 | 0.0 | 0.0 |

34. *Perturbations Due to the Figure of Jupiter.* — Jupiter differs so greatly from a sphere that the usual assumption that it acts upon outside particles as though the entire mass was concentrated at the center will not hold true for bodies approaching Jupiter as closely as did the comet. It becomes desirable, therefore, to compute the disturbances to the motion of the comet, caused by the figure of the planet. The extremely close approach of the comet to the planet's surface plainly indicated large perturbations due to this cause and the asymmetric position of the comet's orbit, relative to the planet's equator, allowed of little balancing of effects on its approach and recession. These perturbations may be readily computed in the following manner.

LaPlace[1] expresses that part of the perturbative function which depends upon the figure of Jupiter in the following form:

$$R = \tfrac{1}{3}(\rho - \tfrac{1}{2}\phi)(1 - 3\sin^2\delta)\frac{MB^2}{r^3}$$

where the factor $(\rho - \frac{1}{2}\varphi)$ depends upon the shape and speed of rotation of the planet; $B$ is the equatorial radius of Jupiter, and $r$ and $\delta$ are respectively the radius vector and jovian declination of the disturbed body. From investigations upon the motions of the satellites the value of the first factor was found by LaPlace[2] to be

$$\log(\rho - \tfrac{1}{2}\phi) = 8.34047$$

From the above expression for the perturbative function can be found by differentiation the disturbing forces in the directions of $r$ and $\delta$; and thence by resolving the latter into its components, the disturbing forces $R$, $S$, and $W$. The formulas for this latter step are rather complicated, unless we first refer the elements of the comet's orbit to Jupiter's equator as fundamental plane, or else neglect the inclination of the latter to the ecliptic. This latter may be done, in the present special case, without introducing any appreciable error, for this inclination is but 3°, while the orbit of the comet was inclined some 64° to the ecliptic. The formulas as thus deduced are, $L$ being an auxiliary angle:

$$\cot L = \cos u \tan i$$

$$\sin \delta = \sin u \sin i$$

$$R_0' = -(1 - 3\sin^2\delta)\frac{C}{r^2}$$

$$S_0' = -(\sin 2\delta \cos L)\frac{C}{r^2}$$

$$W_0' = -(\sin 2\delta \sin L)\frac{C}{r^2}$$

where

$$C = (\rho - \tfrac{1}{2}\phi)B^2$$

[1] *Mécanique Céleste*, Livre VIII, Sec. 1.

[2] *Mécanique Céleste*, Livre VIII, Sec. 27.

and thence

$$R' = \frac{1}{r^2}\,\frac{\omega k}{\sqrt{\rho}}\,R_0'$$

$$S' = \frac{1}{r^2}\,\frac{\omega k}{\sqrt{\rho}}\,S_0'$$

$$W' = \frac{1}{r^2}\,\frac{\omega k}{\sqrt{\rho}}\,W_0'$$

The disturbing forces are therefore proportional to the inverse fourth power of the radius vector; and, hence, for a close approach, the resulting perturbations may become very large. In the case under consideration, these disturbing forces were found to be, at the time of closest approach, as great as one per cent of the central controlling force of Jupiter.

To obtain the perturbations of the elements the disturbing forces, as computed above, are combined with the differential coefficients of the elements as given in §33.

With these formulas I computed the perturbations during the 36 hours of closest approach, July 19.5 to July 21.0, using an interval of one hour except for the eight hours of closest approach, when the interval was reduced to 15 minutes. The following table gives the values of the integrated perturbations, thus derived, at the dates of computation, the changes in $e$, $\nu$ and $N$ being expressed in units of the sixth decimal place.

## Table XV.

### Perturbations Due to Figure of Jupiter.

| Date. | $\Delta\pi$ | $\Delta\Omega$ | $\Delta i$ | $\Delta e$ | $\omega\Delta v$ | $(\Delta N)_{,}$ | $(\Delta N)_{,,}$ |
|---|---|---|---|---|---|---|---|
| d h m | " | " | " | " | " | " | " |
| July 19, 12 0 | + 1.92 | + 77.03 | + 5.94 | + 247.6 | + 15.48 | — 70.22 | —172.34 |
| 13 0 | + 2.12 | + 76.21 | + 5.58 | + 246.8 | + 15.43 | — 69.47 | —156.88 |
| 14 0 | + 2.34 | + 75.25 | + 5.17 | + 245.8 | + 15.38 | — 68.64 | —141.47 |
| 15 0 | + 2.64 | + 74.10 | + 4.74 | + 244.5 | + 15.30 | — 67.60 | —126.13 |
| 16 0 | + 3.00 | + 72.74 | + 4.24 | + 242.7 | + 15.19 | — 66.35 | —110.98 |
| 17 0 | + 3.43 | + 71.05 | + 3.67 | + 240.4 | + 15.05 | — 64.76 | — 95.85 |
| 18 0 | + 3.98 | + 68.93 | + 3.00 | + 237.2 | + 14.86 | — 62.76 | — 80.89 |
| 19 0 | + 4.66 | + 66.24 | + 2.24 | + 232.7 | + 14.57 | — 60.21 | — 66.16 |
| 20 0 | + 5.51 | + 62.73 | + 1.35 | + 226.1 | + 14.16 | — 55.81 | — 51.81 |
| 21 0 | + 6.54 | + 57.80 | + 0.30 | + 215.8 | + 13.52 | — 52.17 | — 37.96 |
| 22 0 | + 8.14 | + 52.70 | — 0.60 | + 199.6 | + 12.48 | — 45.80 | — 24.92 |
| 23 0 | + 9.53 | + 44.18 | — 1.44 | + 170.6 | + 10.67 | — 36.35 | — 13.26 |
| July 20, 0 0 | + 9.18 | + 27.90 | — 1.96 | + 116.0 | + 7.23 | — 18.27 | — 4.17 |
| 1 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | | | | | | |
| July 20, 1 0 | +894.27 | +916.04 | — 21.64 | —1181.8 | — 17.55 | — 47.10 | +358.10 |
| 15 | +888.85 | +906.98 | — 20.42 | —1218.1 | — 18.00 | — 40.42 | +340.33 |
| 30 | +881.58 | +896.82 | — 18.78 | —1260.0 | — 18.50 | — 33.40 | +322.13 |
| 45 | +871.02 | +885.24 | — 16.48 | —1306.2 | — 19.04 | — 26.20 | +303.37 |
| 2 0 | +857.82 | +872.00 | — 13.29 | —1357.5 | — 19.63 | — 19.03 | +284.04 |
| 15 | +837.79 | +856.84 | — 8.91 | —1411.3 | — 20.23 | — 12.15 | +264.06 |
| 30 | +810.20 | +839.58 | — 3.00 | —1463.5 | — 20.80 | — 6.43 | +243.54 |
| 45 | +771.47 | +820.01 | + 4.97 | —1504.7 | — 21.21 | — 2.57 | +222.52 |
| 3 0 | +717.44 | +797.84 | + 15.85 | —1516.4 | — 21.19 | — 0.18 | +201.28 |
| 15 | +643.81 | +773.21 | + 30.58 | —1462.0 | — 20.31 | — 2.90 | +180.44 |
| 30 | +547.02 | +746.94 | + 50.00 | —1284.5 | — 17.84 | — 19.26 | +161.20 |
| 45 | +430.96 | +721.09 | + 74.50 | — 904.3 | — 12.85 | — 47.59 | +145.56 |
| 4 0 | +313.98 | +697.17 | +103.70 | + 148.6 | — 3.93 | — 89.63 | +136.82 |
| 15 | +247.42 | +681.05 | +133.49 | + 849.7 | + 9.23 | —138.82 | +138.94 |
| 30 | +308.80 | +674.83 | +155.24 | +2024.0 | + 23.72 | —179.72 | +155.57 |
| 45 | +519.40 | +674.31 | +157.56 | +2692.1 | + 31.93 | —195.58 | +184.40 |
| 5 0 | +789.26 | +665.55 | +129.86 | +2082.8 | + 24.37 | —199.24 | +214.42 |
| 15 | +920.35 | +630.88 | + 74.51 | + 159.8 | + 1.37 | —208.56 | +228.27 |
| 30 | +776.28 | +561.54 | + 11.85 | —1898.5 | — 23.65 | —231.79 | +216.61 |
| 45 | +159.57 | +467.73 | — 39.77 | —3121.2 | — 38.54 | —259.91 | +184.23 |
| 6 0 | + 52.76 | +369.82 | — 70.85 | —3304.8 | — 41.11 | —267.46 | +143.42 |
| 15 | — 51.65 | +281.76 | — 82.49 | —2835.6 | — 35.53 | —247.27 | +104.72 |
| 30 | —146.86 | +210.74 | — 80.84 | —2170.5 | — 27.46 | —209.69 | + 73.24 |
| 45 | —173.63 | +156.15 | — 72.68 | —1567.6 | — 19.97 | —167.70 | + 49.62 |
| 7 0 | —166.14 | +114.58 | — 62.07 | —1090.0 | — 13.98 | —129.01 | + 32.80 |
| 15 | —143.20 | + 83.54 | — 51.04 | — 740.5 | — 9.60 | — 96.12 | + 21.11 |
| 30 | —120.54 | + 60.46 | — 40.68 | — 496.1 | — 6.49 | — 69.94 | + 13.16 |
| 45 | — 88.71 | + 43.17 | — 31.40 | — 327.2 | — 4.32 | — 49.61 | + 7.81 |
| 8 0 | — 64.78 | + 29.87 | — 23.21 | — 205.8 | — 2.78 | — 33.80 | + 4.30 |
| 15 | — 44.07 | + 19.50 | — 16.08 | — 125.6 | — 1.69 | — 21.59 | + 2.10 |
| 30 | — 27.05 | + 11.42 | — 9.90 | — 66.2 | — 0.91 | — 12.35 | + 0.81 |
| 45 | — 12.33 | + 5.05 | — 4.59 | — 27.7 | — 0.39 | — 5.30 | + 0.18 |
| 9 0 | 0.00 | 0.00 | — 0.00 | — 0.0 | — 0.00 | — 0.00 | + 0.00 |

TABLE XV.—*Continued.*

PERTURBATIONS DUE TO FIGURE OF JUPITER.

| Date. | $\Delta\pi$ | $\Delta\Omega$ | $\Delta i$ | $\Delta e$ | $\omega\Delta\nu$ | $(\Delta N)_{\prime}$ | $(\Delta N)_{\prime\prime}$ |
|---|---|---|---|---|---|---|---|
| d h m | $''$ | $''$ | $''$ | $''$ | $''$ | $''$ | $''$ |
| July 20, 9 0 | — 46.96 | + 21.20 | — 30.06 | — 148.27 | —1.40 | +15.45 | — 11.61 |
| 10 0 | — 21.25 | + 9.49 | — 18.19 | — 45.03 | +1.47 | +18.29 | — 11.06 |
| 11 0 | — 9.78 | + 4.91 | — 11.87 | — 8.35 | —1.83 | +18.15 | — 9.25 |
| 12 0 | — 4.59 | + 2.83 | — 8.21 | + 6.27 | +1.64 | +16.57 | — 7.49 |
| 13 0 | — 2.01 | + 1.76 | — 5.99 | + 12.74 | +1.38 | +14.84 | — 5.99 |
| 14 0 | — 0.72 | + 1.18 | — 4.58 | + 15.93 | +1.14 | +13.23 | — 4.74 |
| 15 0 | — 0.02 | + 0.84 | — 3.62 | + 15.56 | +0.96 | +11.78 | — 3.69 |
| 16 0 | + 0.39 | + 0.62 | — 2.91 | + 12.84 | +0.80 | +10.38 | — 2.81 |
| 17 0 | + 0.43 | + 0.45 | — 2.30 | + 10.64 | +0.66 | + 8.98 | — 2.08 |
| 18 0 | + 0.36 | + 0.32 | — 1.80 | + 8.63 | +0.54 | + 7.60 | — 1.48 |
| 19 0 | + 0.42 | + 0.23 | — 1.37 | + 6.83 | +0.43 | + 6.28 | — 1.00 |
| 20 0 | + 0.40 | + 0.16 | — 1.01 | + 5.21 | +0.33 | + 4.98 | — 0.62 |
| 21 0 | + 0.34 | + 0.10 | — 0.69 | + 3.72 | +0.24 | + 3.65 | — 0.34 |
| 22 0 | + 0.25 | + 0.06 | — 0.42 | + 2.37 | +0.15 | + 2.37 | — 0.15 |
| 23 0 | + 0.14 | + 0.02 | — 0.19 | + 1.13 | +0.08 | + 1.18 | — 0.04 |
| July 21, 0 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

35. *Passage Through Jupiter's Satellite System.*—Taking from the above tables the solar perturbations for July 22.5 and applying them to the hyperbolic elements given in Section 32, I find for the elements, which represent the motion of the comet at the time of its closest approach to Jupiter:

Epoch 1886, July 22.5.

$$\pi = 282^\circ\ 23'\ 43.''5$$
$$\Omega = 254\ \ 15\ \ 16.\ 0$$
$$i = 61\ \ 29\ \ 15.\ 2$$
$$e = 1.0124886$$
$$\nu = 0.0095882$$
$$N = 0.0210245$$

This gives the date of closest approach as

$$\text{July } 20^{\text{d}}\ 5^{\text{h}}\ 6.4^{\text{m}}$$

at which time the comet was only 2.22 radii of Jupiter distant from the center of that body. In other words, the center of the comet was only about one and one quarter radii of Jupiter, or 55,000 miles, distant from the surface of that planet. The comet, therefore, passed well within the orbit of the fifth satellite.

The planes of the orbits of the satellites of Jupiter are all nearly coincident with that of Jupiter's equator, and therefore are inclined but a few degrees to the plane to which is referred the comet's orbit. The elements of the orbit of the comet about Jupiter show that the plane of the comet's orbit cuts that in which the satellites move at a large angle, and further, the difference of longitudes of the perijove and the ascending node was only about $28\frac{1}{4}°$. Thus, at the ascending node the comet crossed the line of nodes at a large angle; while near the descending node the path of the comet was for a time nearly parallel to the line of nodes. Hence, as the comet neared Jupiter, there could be no close approach to any of the satellites, excepting very near the node. But, on the other hand, as the comet receded from the planet, it hovered over the satellites and close approaches might occur at considerable distances from the descending node.

This is shown in Plate I, which is approximately to scale, and in which the orbits of the five satellites are projected upon the plane of reference, and are, therefore, seen nearly in their true size. The orbit of the comet was in a plane inclined 60° to this and intersecting it in the line of ☊☋. The comet rose up suddenly from below the plane of the satellites' orbits, crossing it nearly at right angles, at ☊; then passed rapidly upward and almost directly over Jupiter and then slowly descended and finally passed below this plane again at ☋. From the time the comet passed the ascending node, at ☊, until it left the satellite system at the descending node, was only 30 hours, of which time only one half ($\frac{1}{2}$) hour was necessary to carry the comet from the ascending node to perijove.

During the time in which the comet was in the vicinity of Jupiter and its satellites, it was moving so rapidly that nothing except a very close approach could have any appreciable influence. Indeed, to have caused any noticeable alteration in the relative orbit about Jupiter, the comet must have passed within the "sphere of attraction" of the disturbing satellite. Now the distances of the satellites and the radii of their various "spheres," taken in reference to Jupiter, are given in the table

below, where the unit of distance is the equatorial semi-diameter of Jupiter.

| | Distance. | Sphere. |
|---|---|---|
| Satellite I | 5.93 | 0.065 |
| Satellite II | 9.44 | 0.118 |
| Satellite III | 15.06 | 0.320 |
| Satellite IV | 26.49 | 0.420 |

These values being obtained from the masses and distances as given by Newcomb.

The following table shows at a glance the character of the approach to each of the four satellites: the first column contains the number of the satellite, the second the smallest possible distance between the orbit of the satellite and that of the comet in terms of the radius of Jupiter, and the third column the radius of the sphere of attraction of the satellite.

| Satellite. | Least Distance. | Sphere. |
|---|---|---|
| I | 3.57 | 0.06 |
| II | 4.16 | 0.12 |
| III | 4.01 | 0.32 |
| IV | 2.62 | 0.42 |

Thus there was no approach near enough to cause the slightest change in the relative orbit of the nucleus about Jupiter. In no case did the nucleus pass nearer to the satellite than six times the radius of the "sphere of attraction" of that satellite; and at this distance the perturbations of the satellite would be inappreciable.

36. Again, as to the disruption of the comet; the above shows pretty clearly that it could not have been caused by the action of any one of the four outer satellites. For the radius of the comet, although a very uncertain quantity could hardly have been larger than the radius of Jupiter, and in no possible case did any of the cometary matter pass within the "sphere" of a satellite.

In all that goes before, the fifth satellite has been left out of consideration. The mean distance of this body is about 2.6 radii of Jupiter, while the distance of the ascending node of the comet's orbit was only 2.36 radii. Thus if the satellite was in

that part of its orbit at the time the comet passed its node, a collision of the two bodies was almost inevitable; the satellite passing through the comet. But there is still uncertainty as to the exact moment at which the satellite was in this portion of its orbit. Hence it is impossible to say definitely whether three was or was not a collision. It is therefore possible that the observed disruption of the comet was caused by the action of this satellite. But all things considered, it is more probable, I think, that it was caused by the action of Jupiter itself.

37. *Transformation to the Sun as Center.* — From the tables of the solar perturbations and from those of the pertubations due to the elliptic figure of Jupiter I find that the total perturbations for the interval between October 26.5 and March 24.5 are as follows:

PERTURBATIONS.

| | Solar. | Figure. |
|---|---|---|
| $\Delta\pi$ | $+\ 0°31'42''.6$ | $+0°14'\ 9''.3$ |
| $\Delta\Omega$ | $-\ \ 2\ \ 1\ 10\ .2$ | $+0\ 16\ 54\ .3$ |
| $\Delta i$ | $-11\ \ 9\ 34\ .5$ | $-0\ \ 0\ 45\ .8$ |
| $\Delta e$ | $+0.0016832$ | $-0.0010825$ |
| $\Delta \nu$ | $-0.0004252$ | $-0.0013468$ |
| $\Delta N$ | $+0.0400961$ | $+0.0010143$ |

Applying these to Hyberbolic Elements I, as given in 32, I have for the hyperbolic elements which represent the motion of the comet about Jupiter on March 24.5, 1886, the following:

Epoch, 1886, March 24.5

| | | |
|---|---|---|
| $\pi =$ | $284°\ 7'20''.1$ | $+271''.290\nu$ |
| $\Omega =$ | $256\ 23\ \ 4\ .6$ | $-\ \ 12\ .294\nu$ |
| $i =$ | $63\ 29\ \ 3\ .2$ | $-\ \ 97\ .957\nu$ |
| $e =$ | $1.0099530$ | $+0.0001826\nu$ |
| $\nu =$ | $0.0074203$ | $+0.00000168\nu$ |
| $N =$ | $-0.8821586$ | $+0.00056784\nu$ |

The perturbations, as above, were computed with the elements corresponding to $\nu = 0$, and rigorously, therefore, the results only apply to the mean hyperbola and not to hyperbolas corresponding to various values of $\nu$. The perturbations, especially those due to the figure of Jupiter, for these hyperbolas, would undoubtedly differ considerably from those derived for

the mean hyperbola, but on account of the great labor involved in making separate determinations for the different values of $\nu$, I used the mean values and applied them directly to the various hyperbolas with the results as above given.

From these elements were computed the rectangular coördinates and velocities of the comet in reference to Jupiter as center as below:

$$\begin{aligned}
\log x &= 8.4208419\,n \\
\log y &= 9.4298307 \\
\log z &= 9.2511007\,n \\
\log \frac{dx}{dt} &= 6.1427545 \\
\log \frac{dy}{dt} &= 7.2597800\,n \\
\log \frac{dz}{dt} &= 7.0525958
\end{aligned}$$

The coördinates and velocities of Jupiter about the sun were found in the manner already explained in 31 and were:

$$\begin{aligned}
\lambda &= 181^\circ 20'\ 4''.82 \\
\beta &= \phantom{18}1\ \ 17\ \ 50\ \ .70 \\
\log r &= 0.7364961 \\
\Delta\lambda &= +\,0^\circ 4' 32''.206 \\
\Delta\beta &= +\,0\ \ 0\ \ 0\ .868 \\
\Delta \log r &= +\,0.00000581
\end{aligned}$$

From these were easily computed the rectangular coördinates and velocities of Jupiter in reference to the sun. Combining these with the coördinates and velocities of the comet, as given above, were found the heliocentric rectangular coördinates and velocities of the comet, as follows:

$$\begin{aligned}
\log x &= 0.7383624\,n \\
\log y &= 9.1526213 \\
\log z &= 8.7391814\,n \\
\log \frac{dx}{dt} &= 6.3693435 \\
\log \frac{dy}{dt} &= 7.9547556\,n \\
\log \frac{dz}{dt} &= 7.0619536
\end{aligned}$$

From these were derived, by means of the formulas in 32, the expressions for the three constants of area, $C$, $C'$, $C''$, that for

the semi-axis major of the comet's orbit about the sun and the auxiliary quantities $f, f'$ as follows:

$$\begin{aligned}
\log C &= 8.6928251 \\
\log C' &= 7.7994321\, n \\
\log C'' &= 6.5189619\, n \\
\log a &= 1.0649320 \\
\log f &= 6.1922104\, n \\
\log f' &= 5.2922140\, n
\end{aligned}$$

and consequently the resulting orbit is an ellipse of 39.57 years period.

From the above quantities were derived the complete elliptic elements which represent the osculating ellipse in which the comet was travelling about the sun on March 24.5 1886. These elements are:

Epoch, March 24.5 1886

$$\begin{aligned}
\mu &= \phantom{187^\circ 12'} 89''.66204 + \phantom{19}0''.111837\, \nu \\
\pi &= 187^\circ 12' 33''.7 + 194''.392\, \nu \\
\Omega &= 183 \quad 0 \quad 3\ .4 + 108\ .157\, \nu \\
i &= \phantom{18}7 \quad 17 \quad 38\ .7 + \phantom{1}96\ .434\, \nu \\
\omega &= \phantom{18}4 \quad 12 \quad 30\ .3 + \phantom{1}86\ .235\, \nu \\
\phi &= \phantom{1}32 \quad\ 1 \quad 26\ .6 - 100\ .309\, \nu \\
M &= -2 \quad 16 \quad 59\ .5 - \phantom{1}57\ .614\, \nu
\end{aligned}$$

The date of perihelion passage was found to be,

$$1886 \text{ June } 24.1723 + 0^d.51688\, \nu.$$

The coefficients of $\nu$ in the above were found by independent caculations. In the hyberbolic elements of March 24.5 $\nu$ was made equal to $+10$ and the resulting elliptic elements found in a manner entirely similar to that above explained. These elements were then compared with the constant parts of the above elements, which correspond to $\nu = 0$ and the differences divided by 10. The results are the coefficients in question.

In making these transformations from hyperbola to ellipse the check already described was again successfully applied.

38. *Perturbations Previous to 1886.*—The elements just given represent the osculating orbit which the comet was describing at the moment it entered Jupiter's sphere of activity. For some months before this time the planet and comet were

so close together that the orbit of the latter was continually subject to change and it was, therefore, necessary to compute the perturbations of the comet by the planet for this interval. For this purpose the ordinary method of the variation of constants was used and in order to take account of the terms of the second and higher orders the variable elements for each date were used in the computations. The intervals of computation were as follows: from 1886 March 24.5 to 1885 December 14.5 ten days and from the latter date to 1883 February 8.5, forty days. During this time Jupiter alone was considered and all the computations were made with those elements which correspond to $\nu$ equal to zero. Of course the perturbations thus obtained apply to the mean set of elements only; but I have applied them directly to the various sets of elements, as represented by different values of $\nu$, without regard to the changes that might be introduced by separate computations.

The integrated values of these perturbations for each date of computation are given in the table on the following page.

Applying these perturbations the resulting osculating and definitive elements of the comet on February 8.5 1883 are as follows:

Elements VI.

Epoch, 1883, February 8.5.

$$
\begin{array}{rl}
\mu = & 121''.4483 + 0''.11184\,\nu \\
L = & 146^\circ\ 6'\ 28''.4 + 9''.280\,\nu \\
\pi = & 188\ \ 40\ \ 1\ .7 + 194\ .392\,\nu \\
\Omega = & 186\ \ 57\ \ 40\ .6 + 108\ .157\,\nu \\
\phi = & 24\ \ 56\ \ 11\ .1 - 100\ .309\,\nu \\
i = & 6\ \ 18\ \ 2\ .9 + 96\ .434\,\nu \\
M_0 = & -\ 42\ \ 33\ \ 33\ .3 + 185\ .112\,\nu
\end{array}
\left.\begin{array}{l} \\ \\ \\ \\ \\ \end{array}\right\} 1886.0
$$

and the definitive period of the comet is found to be:

$$29^{y}.22 - 0^{y}_{.}.028\,\nu$$

Julian years, and the date of perihelion passage is,

1886 July 24.06.

## Table XVI.

### Purturbations by Jupiter 1883 to 1886.

| Date. | $\Delta\pi$ | $\Delta\Omega$ | $\Delta i$ | $\Delta\phi$ | $\Delta\mu$ | $(\Delta L)_{,}$ | $(\Delta L)_{,,}$ |
|---|---|---|---|---|---|---|---|
| | ° ′ ″ | ° ′ ″ | ° ′ ″ | ° ′ ″ | ″ | ° ′ ″ | ° ′ ″ |
| 1883 Feb. 8.5 | +0 57 14.8 | +3 22 19.4 | −0 31 34.8 | −3 49 0.0 | +17.3033 | −1 45 54.6 | −3 58 48.24 |
| Mch. 20.5 | +0 58 6.1 | +3 21 6.6 | −0 31 34.2 | −3 47 59.0 | +17.2707 | −1 44 16.0 | −3 47 16.83 |
| Apr. 29.5 | +0 59 2.0 | +3 19 37.7 | −0 31 33.2 | −3 46 52.1 | +17.2327 | −1 42 27.2 | −3 35 46.84 |
| June 8.5 | +1 0 1.3 | +3 17 49.6 | −0 31 31.6 | −3 45 37.4 | +17.1880 | −1 40 29.5 | −3 24 18.50 |
| July 18.5 | +1 1 2.7 | +3 15 39.0 | −0 31 29.1 | −3 44 16.7 | +17.1345 | −1 38 19.2 | −3 12 52.10 |
| Aug. 27.5 | +1 2 4.3 | +3 13 2.9 | −0 31 25.4 | −3 42 45.3 | +17.0697 | −1 35 55.9 | −3 1 28.00 |
| Oct. 6.5 | +1 3 3.7 | +3 9 58.5 | −0 31 20.5 | −3 41 2.8 | +16.9905 | −1 33 19.2 | −2 50 6.81 |
| Nov. 15.5 | +1 3 58.2 | +3 6 23.0 | −0 31 13.5 | −3 39 7.4 | +16.8937 | −1 30 28.1 | −2 38 49.11 |
| Dec. 25.5 | +1 4 44.5 | +3 2 13.5 | −0 31 4.4 | −3 36 56.6 | +16.7757 | −1 27 22.2 | −2 27 35.68 |
| 1884 Feb. 3.5 | +1 5 19.5 | +2 57 27.5 | −0 30 52.6 | −3 34 28.0 | +16.6315 | −1 24 0.8 | −2 16 27.46 |
| Mch. 14.5 | +1 5 39.3 | +2 52 2.9 | −0 30 37.5 | −3 31 38.9 | +16.4575 | −1 20 24.0 | −2 5 26.19 |
| Apr. 23.5 | +1 5 49.4 | +2 46 6.0 | −0 30 18.3 | −3 28 28.3 | +16.2538 | −1 16 33.8 | −1 54 31.83 |
| June 2.5 | +1 5 38.8 | +2 39 27.8 | −0 29 54.3 | −3 24 49.9 | +16.0088 | −1 12 31.1 | −1 43 46.44 |
| July 12.5 | +1 5 5.5 | +2 32 6.1 | −0 29 24.5 | −3 20 38.7 | +15.7160 | −1 8 15.8 | −1 33 11.77 |
| Aug. 21.5 | +1 4 4.2 | +2 24 2.8 | −0 28 48.4 | −3 15 50.2 | +15.3680 | −0 3 49.6 | −1 22 49.89 |
| Sept. 30.5 | +1 2 32.0 | +2 15 18.6 | −0 28 4.7 | −3 10 18.0 | +14.9560 | −0 59 13.4 | −1 12 43.18 |
| Nov. 9.5 | +1 0 26.2 | +2 5 54.1 | −0 27 12.5 | −3 3 55.4 | +14.4712 | −0 54 27.9 | −1 2 54.37 |
| Dec. 19.5 | +0 57 44.4 | +1 55 50.1 | −0 26 10.3 | −2 56 33.1 | +13.9008 | −0 49 33.7 | −0 50 6.62 |
| 1885 Jan. 28.5 | +0 54 24.1 | +1 45 8.9 | −0 24 56.4 | −2 48 0.4 | +13.2310 | −0 44 32.0 | −0 44 23.64 |
| Mch. 9.5 | +0 50 23.7 | +1 33 52.8 | −0 23 29.2 | −2 38 4.2 | +12.4448 | −0 39 13.4 | −0 35 49.70 |
| Apr. 18.5 | +0 45 41.3 | +1 22 1.1 | −0 21 45.5 | −2 26 25.1 | +11.5182 | −0 34 7.3 | −0 27 49.93 |
| May 28.5 | +0 40 14.7 | +1 9 35.0 | −0 19 41.9 | −2 12 38.9 | +10.4205 | −0 28 43.9 | −0 20 30.53 |
| July 7.5 | +0 34 1.7 | +0 56 35.6 | −0 17 13.6 | −1 56 11.8 | + 9.1090 | −0 23 13.0 | −0 13 59.15 |
| Aug. 16.5 | +0 26 59.1 | +0 43 4.2 | −0 14 14.1 | −1 36 15.1 | + 7.5242 | −0 17 34.0 | −0 8 25.48 |
| Sept. 25.5 | +0 19 2.8 | +0 29 3.4 | −0 10 33.3 | −1 11 39.4 | + 5.5800 | −0 11 47.4 | −0 4 2.06 |
| Nov. 4.5 | +0 10 7.2 | +0 14 38.3 | −0 5 56.8 | −0 40 36.9 | + 3.1448 | −0 5 54.0 | −0 1 5.73 |
| Dec. 14.5 | 0 0 0.0 | 0 0 0.0 | 0 0.0 | 0 0.0 | 0.0000 | 0 0.0 | 0 0 0.00 |
| Dec. 14.5 | +0 30 13.2 | +0 35 17.8 | −0 28 1.0 | −3 16 15.5 | +14.4830 | −0 15 51.0 | − 13 55.00 |
| Dec. 24.5 | +0 27 30.0 | +0 31 57.2 | −0 26 28.5 | −3 4 11.0 | +13.5560 | −0 14 6.0 | 0 11 34.90 |
| 1886 Jan. 3.5 | +0 24 55.8 | +0 28 7.6 | −0 24 27.7 | −2 50 38.8 | +12.5240 | −0 12 23.8 | −0 9 24.42 |
| Jan. 13.5 | +0 22 8.2 | +0 24 19.6 | −0 22 17.8 | −2 35 58.8 | +11.4120 | −0 10 45.4 | −0 7 24.69 |
| Jan. 23.5 | +0 19 17.4 | +0 20 33.8 | −0 19 56.3 | −2 19 55.6 | +10.2000 | −0 9 9.7 | −0 5 36.51 |
| Feb. 2.5 | +0 16 36.4 | +0 16 48.7 | −0 17 20.0 | −2 2 12.3 | + 8.8740 | −0 7 22.7 | −0 4 1.06 |
| Feb. 12.5 | +0 13 42.5 | +0 13 8.9 | −0 14 29.6 | −1 42 42.3 | + 7.4250 | −0 5 39.0 | −0 2 39.43 |
| Feb. 22.5 | +0 10 49.0 | +0 9 36.9 | −0 11 24.8 | −1 21 15.2 | + 5.8640 | −0 3 53.9 | −0 1 32.93 |
| Mch. 4.5 | +0 7 49.1 | +0 6 13.5 | −0 8 0.7 | −0 57 20.0 | + 4.1370 | −0 2 11.6 | −0 0 42.70 |
| Mch. 14.5 | +0 3 45.0 | +0 2 59.1 | −0 4 12.3 | −0 30 17.9 | + 2.1730 | −0 1 12.2 | −0 0 10.99 |
| Mch. 24.5 | 0 0 0.0 | 0 0 0.0 | 0 0.0 | 0 0 0.0 | 0.0000 | 0 0 0.0 | 0 0 0.00 |

39. We have seen that there were large disturbances in the motion of the comet due to the figure of Jupiter. In section 34 were calculated the perturbations of the hyperbolic elements due to this cause and the results there obtained were used in all calculations. Elements VI, therefore, depend upon the numerical accuracy with which these perturbations were computed. As these were difficult to calculate, owing to the very close approach of the nucleus to the surface of the planet, it is of interest to show, in a direct manner, the effect of these disturbances upon the motion of the comet. In order to do this I made an independent calculation of the path of the nucleus about Jupiter, omitting the perturbations due to figure, but retaining those due to the sun.

The hyperbolic elements which represent the path of the comet about Jupiter on October 26.5 1886, and which were given in section 32 were made the basis of the new computation.

To these elements were applied the solar perturbations for the interval between October 26.5 and March 24.5 and thus were found the hyperbolic elements which represent the motion of the comet about Jupiter on March 24.5. These elements differ but little from those given in the previous section, except in $\nu$ and $N$, where the perturbations due to figure were quite large. From these elements were deduced the elliptic elements, which represent the motion of the comet about the Sun on March 24.5, in a manner entirely similar to that explained in 37, and which were found to be:

Epoch, March 24.5 1886.

$$\begin{array}{rl} \mu = & 83''.8702 \\ \pi = & 187^\circ 11' \; 7''.88 \\ \Omega = & 183 \;\; 7 \; 16 \; .87 \\ i = & 7 \; 30 \; 48 \; .47 \\ \omega = & 4 \;\; 3 \; 51 \; .01 \\ \phi = & 33 \; 25 \;\; 6 \; .99 \\ M = & -2 \;\; 8 \; 24 \; .48 \end{array} \quad \left.\begin{array}{l} \\ \\ \\ \\ \\ \end{array}\right\} 1886.0$$

In these elements the coefficients of the indeterminate $\nu$ would be nearly the same as those given for the corresponding ele-

ments in section 37. As these elements differed considerably from those given in 37, the perturbations by Jupiter for some months previous to 1886 were recomputed with the new elements as a basis and the above elements were carried back to 1883 and were found to be:

ELEMENTS VII.

Epoch, February 8.5 1883

$$\left.\begin{array}{l} \mu = 112''.7340 \\ \left.\begin{array}{l} L = 147^\circ 48'\ 31''.4 \\ \pi = 188\ 36\ 49\ .6 \\ \Omega = 186\ 36\ \ 9\ .2 \\ \varphi = \ 26\ 46\ 26\ .3 \end{array}\right\}\ 1886.0 \\ i = \ \ 6\ 38\ 31\ .8 \end{array}\right.$$

and the corresponding period of the comet is

31.47

Julian years.

This period, 31.47 years, is about two and a quarter years longer than the definitive period obtained from Elements VI. Thus the disturbances due to the figure of Jupiter had a decided effect upon the motion of the nucleus of the comet; an effect large enough to sensibly modify the final conclusions in regard to the identity of this comet with that of Lexell. These disturbances and their effects are considerably larger than those obtained in a former investigation.[1] This is due to the fact that the comet approached Jupiter much more closely than was indicated by the elements used in the former work.

Even if we consider that the perturbations due to the figure of Jupiter, as computed in section 34, as approximately correct only, we can, nevertheless, safely conclude that the period of this comet previous to 1883 was not less than 29.2 and not greater than 31.5 years.

[1] "Researches upon Comet 1889 *v*," *Astr. Jour.*, 309, p. 177.

## As to Identity with Comet 1770 (Lexell).

40. Lexell's comet underwent its notable disturbance in the year 1779 and, moreover, this disturbance took place in that part of Jupiter's orbit in which Comet 1889 (Brooks) suffered its great change of elements in the year 1886. Between these two appulses there intervened a period of 107 years, which period must be accurately accounted for in order to establish the identity of these two remarkable bodies. But, assuming the substantial correctness of the present investigation, we cannot directly account for these years. For the period of Comet 1889 (Brooks) in 1883, or previous to its disturbance, has been shown to be $29.22 \pm 0.03$ years, which is not an aliquot part of 107. Hence, unless in the intervening years the comet suffered other and marked disturbances in its orbit, the entire question as to the identity between the bodies disappears.

An investigation shows us that such disturbances may have taken place during this interval, but leaves us uncertain as to the resulting changes in the orbit. Elements VI represent the motion of the comet previous to 1883 and, assuming for the moment that the comet suffered no perturbations before that date, we can find the approximate dates at which the comet may have approached sufficiently near to Saturn or to Jupiter to have had its motion appreciably disturbed.

41. *Approaches to Saturn.* The orbits of the two bodies, Saturn and the comet, intersect in longitudes 79° and 298°; the comet and Saturn being in these respective longitudes at the times given in the following table:

Table XVII.

| Longitude 79. | | | Longitude 298. | | |
|---|---|---|---|---|---|
| Comet. | Saturn. | Diff. | Comet. | Saturn. | Diff. |
| 1881.7 | 1884.9 | 3.2 | 1862.3 | 1873.7 | 11.4 |
| 1852.5 | 1855.4 | 2.9 | 1833.1 | 1844.2 | 11.1 |
| 1823.3 | 1825.9 | 2.6 | 1803.9 | 1814.7 | 10.8 |
| 1794.1 | 1796.4 | 2.3 | 1774.7 | 1785.2 | 10.5 |

Thus in longitude 298° there could be no possible approach; Saturn being in a widely different part of its orbit when the comet reached this point. On the other hand when the comet reached longitude 79°, Saturn was only about 30° from the same point. This, however, made the distance between the two bodies so great that the resulting perturbations were inappreciable. It will be noted, however, that if the average period of the comet previous to 1881 had been 28.5 years then the comet and Saturn would have both reached the common point of their orbits at nearly the same time in 1796; and if the period had been 27.9 years there would have been a close appulse of the two bodies in 1825. Such approaches are not indicated by the definitive elements, the smallest value for the period being 29.2 years. Unless, therefore, during the interval between 1825 and 1881 there were other perturbations sufficient to appreciably change the orbit of the comet, there could have been no close approach to Saturn. This fact, that there could have been no large disturbance by Saturn, is of special importance, as we shall see hereafter.

42. *Approaches to Jupiter.* The definitive set of elements shows that the period of the comet previous to 1883 was 29.2 years, while that of Jupiter is 11.86 years. These two periods are incommensurable, but are somewhat in the ratio of 5 to 2: five periods of Jupiter being equal to 59.3 years, whilst two periods of the comet are equal to 58.4 years. Thus the mean set of elements would indicate that the comet passed perihelion in longitude 188° in February 1828 whilst Jupiter passed the same point about ten months previously. The comet, being at perihelion, was moving more rapidly than Jupiter and gained upon that planet. In the years, 1829 and 1830, therefore, the planet and comet were sufficiently close together for the latter to cause appreciable perturbations. Had the periodic time of the comet been slightly larger than that indicated by the definitive elements, this appulse of the comet and Jupiter in 1828 would have been extremely close.

In order to form some idea as to the character of this appulse the perturbations for the interval between 1883 and 1830 were

approximately computed. The changes for the elements $\mu$ and $L$ were alone considered and intervals of 200 and 400 days were used in the computations. The total perturbations during this interval were found to be small, the integrated values for Feb. 1.5 1831 being,

$$\Delta\mu = -\ 0''.4763$$
$$\Delta L = -\ 41'\ 30''$$

And the resulting elements of the comet for this epoch are,

$$\left.\begin{array}{l} \mu = \ 120''.9720 \\ L = 223^\circ\ 13'\ 40'' \\ \pi = 187\ \ 57\ \ \ 0 \\ \Omega = 186\ \ 13\ \ 20 \\ \phi = \ 24\ \ 56\ \ 11 \\ \iota = \ \ \ 6\ \ 17\ \ 40 \end{array}\right\} 1831.0$$

The closest approach of the comet to Jupiter occurred in the latter part of 1828, but at no time did the comet approach Jupiter closer than six times the radius of the latter's sphere of activity. Hence the resulting perturbations were too small to cause any decided change in the orbit of the comet.

Thus the definite elements do not indicate any close approach of the comet to either Jupiter or Saturn during the interval between 1779 and 1886.

43. There is another method by which the question of identity may be investigated, and that is, by means of the criterion formulated by Tisserand. By an investigation of the path of a comet through the planet's sphere of activity Tisserand derived a function, $n$, of the comet's elements, which remains practically unaltered however great the change in the separate elements. This function is given by the formula,[1]

$$n = \frac{1}{a} + \frac{2\sqrt{A}}{R^2} \cos i \sqrt{p}$$

Where $a$, $p$, and $i$ are respectively the semi-axis major, the parameter and the inclination of the comet's orbit, and $A$ and $R$, the semi-axis major and the radius vector of the disturbing

[1] Mécanique Celeste, Vol. IV, p. 203.

planet at the point of closest approach. Now the action of Jupiter, even when repeated at several very close appulses, can cause but a slight variation in the value of this function, when taken in respect to that planet: but, on the other hand, the action of another planet, Saturn for example, may at one approach change considerably the value of this quantity taken with respect to Jupiter, although it must leave unchanged the value of the function taken with respect to Saturn itself.

Hence, in order to establish the identity of Comet Brooks with that of Lexell both of which were disturbed by Jupiter, we must either show that the $n$'s for the two bodies are practically the same or that there was an intermediate disturbance by another planet.

The values of this function for the two comets under discussion and taken with respect to Jupiter are given below. In order to show the possible variations of $n$ due to one approach, I computed its values with those elements of Comet Brooks which correspond to the following three points of its path: (1) February 1883, the action of Jupiter insensible; (2) March 24, 1886, entrance into the sphere of activity; (3) September 30, 1889, the action of Jupiter again insensible. For Lexell's comet I used the elements as given by Le Verrier

| | | | |
|---|---|---|---|
| Comet | Brooks | (1), | $n = 0.5308$ |
| " | " | (2), | $n = 0.5253$ |
| " | " | (3), | $n = 0.5294$ |
| Comet | Lexell, | | $n = 0.4852$ |

The three values derived for the Brooks comet are in striking accord. We thus see that even this remarkably close approach produced only a total change of $-0.0014$ in the value of this function and, as the change necessary to bring it into agreement with that for Lexell is $-0.0456$, we at once conclude that no intermediate approach or series of approaches to Jupiter can satisfy the requirements of this criterion. This tends to prove, as was long ago pointed out by Schulhof,[1] that the two comets, Lexell and Brooks, are not identical, unless it

[1] Bulletin Astronomique, December, 1889.

can be shown that there was a strong intermediate disturbance by Saturn.

44. In 42 it was shown that if the periodic time of Comet Brooks in 1883 had been slightly larger than that indicated by the definitive elements, then the comet and Jupiter would have had an extremely close appulse in 1827. In fact had the period of the comet previous to 1883 been 29.6 years, then two periods of the comet would have been exactly equal to five of Jupiter and the two bodies would have been together in 1827. This period, 29.6 years, differs only four tenths of a year from the period indicated by the definitive elements and it is not at all impossible that the definitive period may be in error by that amount. In 39 it was shown that the perturbations due to the figure of Jupiter made nearly two and one quarter years difference in the period; that the period, derived by omitting these perturbations, was 31.5 years. Hence if the numerical values of the perturbations due to the figure of Jupiter, as found in 34, are some 18 per cent. too large, then the periodic time of the comet previous to 1883 would have been just 29.6 years. As these perturbations vary inversely as to the fourth power of the distance of the comet from Jupiter, a change of some 5 per cent. or 4,000 miles, in the peri-jovian distance of the comet would fully account for the necessary change in these perturbations. In other words, if the comet passed Jupiter, at the time of closest approach, some 4,000 miles, or one tenth radius of the planet, further from the planet than is indicated by the definitive elements, then two periods of the comet previous to 1883 were equal to five of Jupiter and the two bodies were in close approach in 1827.

45. By making various suppositions as to the period between 1827 and 1883 we can give to the appulse to Jupiter in 1827 any character that we desire. It is worthy of note, however, that for the definitive period of 29.2 years and for any period between that and 29.6 years, the perturbations of $\mu$ in 1827 were of a character such as to increase the periodic time of the comet; that is, previous to 1827 the periodic time of the comet would have been smaller than it was after that date. If this

periodic time of the comet, previous to 1827, was approximately 24 years then the comet and Saturn would have been in the same parts of their respective orbits in longitude 300° for many months in 1786–87, and large disturbances in the comet's motion would have resulted. Slightly different values of the period would have caused the comet to have approached Saturn in longitude 0° in 1790, or in longitude 70° in 1795. We thus see that with elements differing but little from the definitive values a close approach to Saturn is indicated.

46. While an approach to Saturn at some time between 1786 and 1794 is not improbable, yet the uncertainty of the problem is such that we cannot form any idea as to the effect of such approach. In accordance with Tisserand's criterion such an approach, with resultant large disturbances, is necessary to establish the identity of comets Brooks and Lexell. From what we have seen it is, therefore, not impossible that the disturbances by Saturn were of such a character as to satisfy this criterion and it is not impossible, therefore, that the two comets are identical. The numerical results of the present investigation are not conclusive, therefore, as to the non-identity of these two comets. These results indicate the probability of large perturbations by Jupiter in 1827; the possibility of a close approach to Saturn in 1786–94 and a consequent faint possibility of the comet having been in 1779 in the neighborhood of Jupiter at the time when Lexell's comet underwent its notable disturbance. Even if the numerical results showed that the comet was in the vicinity of Jupiter in 1779, when Lexell's comet disappeared, this would not of itself prove the identity of the two bodies, although it would render such identity highly probable. In this connection it would be well to recall the researches of Schulhof on the path of Comet Swift (1895 II) and the possibility of its identity with that of Lexell.

47. In this paper Schulhof[1] showed that the elements of Comet Swift, as deduced from observations, were slightly indeterminate. He showed that the comet had suffered disturb-

[1] Recherches sur l'orbite de la Comète Swift (1895, II), avant 1884. Bulletin Astronomique, March, 1897.

ances by Jupiter in 1886 and in 1837; that the $n$'s for this comet and for Lexell were nearly the same and that, therefore, Tisserand's criterion was approximately satisfied. The effect of the disturbance in 1886 was determined with considerable accuracy, but the effect of the disturbance in 1837 could not be directly calculated, and before that date the uncertainty of the path of the comet became considerable. Schulhof further showed, upon suppositions which are in accord with the known elements of the body, that it was possible for Comet Swift to have been within the sphere of Jupiter's activity at the same time that Lexell's comet was known to have been within that sphere in 1779. Yet Schulhof only concludes that the identity of the two comets is possible.

The evidence in support of the supposed identity of Comet Swift (1895, II) with that of Lexell (1770) is stronger than that which can be brought forward in support of the suspected identity of Comet Brooks (1889, V) with Comet Lexell.

## Conclusions.

(*a*) The results of this investigation go very far towards proving the non-identity of Comets Brooks and Lexell, although they are not conclusive and admit the possibility of such an identity.

(*b*) The computations upon which Chandler based his conclusion of identity of these two bodies are shown to be insufficient on account of the omission of certain important perturbations.

(*c*) Any conclusions as to the path of the comet previous to 1886 must depend to a large extent upon the perturbations suffered by the comet while in the immediate vicinity of Jupiter and due to the elliptical figure of that planet. In any further discussion of the path of this comet these figure perturbations must be most carefully investigated.

## PLATE I.

PLATE I.

Passage of Comet Brooks through Jupiter's Satellite system. The plane of the drawing passes through the center of Jupiter and is parallel to the ecliptic. The orbits of the Satellites are inclined approximately 2° to this plane: the orbit of the comet is inclined 61° to this plane and intersects the plane of reference in the line ☊ ☋. See pp. 277–280.

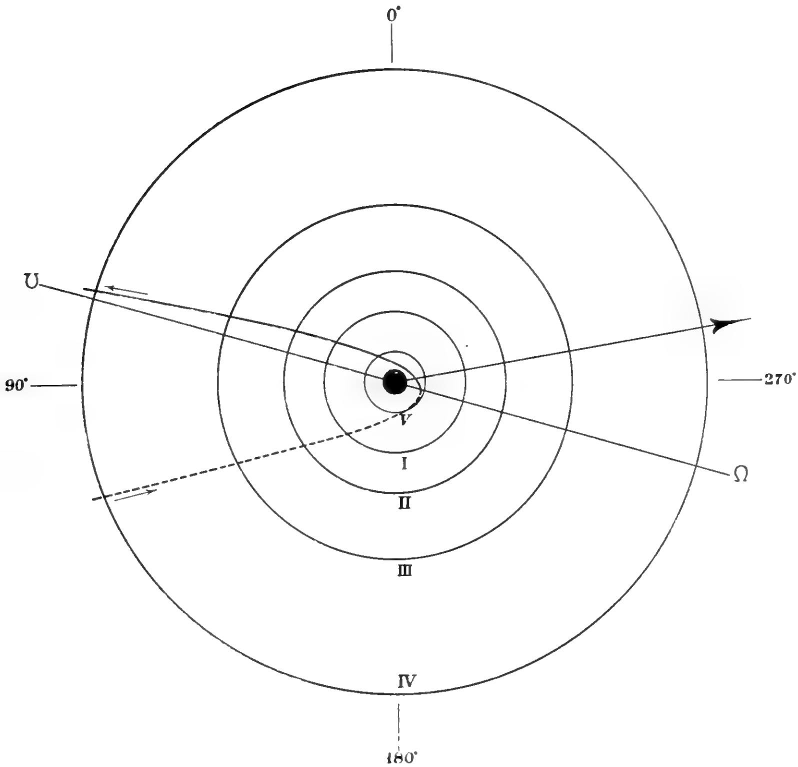
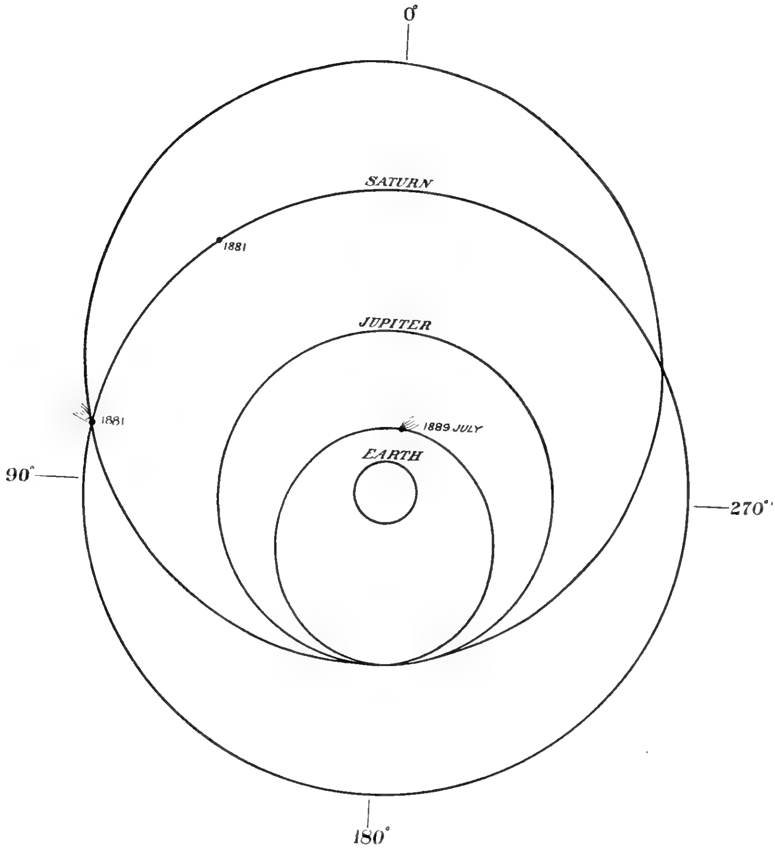

0°
90°
270°
180°
V
I
II
III
IV
℧
Ω

PLATE II.

## PLATE II.

New and Old Orbits of Comet Brooks. The present orbit of the comet is the small ellipse on which the position of the comet is shown at the time of its discovery in 1889. The old orbit of the comet is the large ellipse on which the position of the comet in 1881 is shown. The appulse to Jupiter occurred in 1886 in longitude 188°, near the point of tangency of the two ellipses.


0°
SATURN
1881
JUPITER
1881
1889 JULY
EARTH
90°
270°
180°

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# GENERAL INDEX TO VOLUME XV.

Names of authors in **heavy face type.**

Titles of papers in SMALL CAPS.

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